IRKUTSK NATIONAL RESEARCH TECHNICAL UNIVERSITY

- History of computer development
- Computer architecture
- Computer hardware: basic components

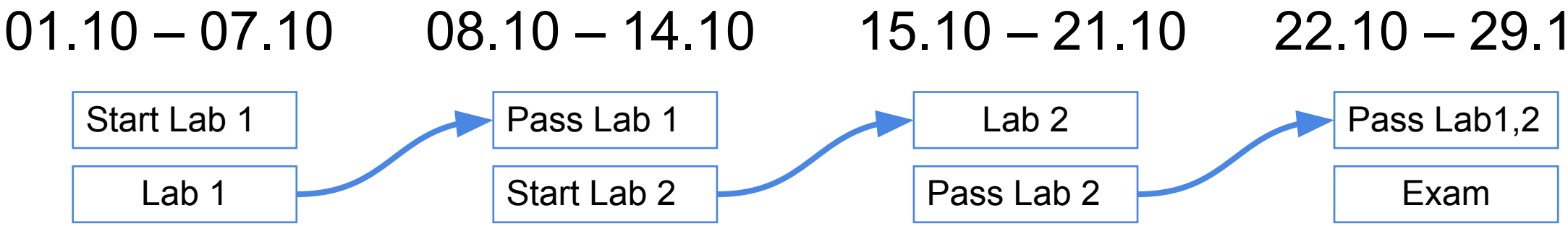
Software and Computing

Lecture 1

Associate professor: Poletaev Alexander

Course structure

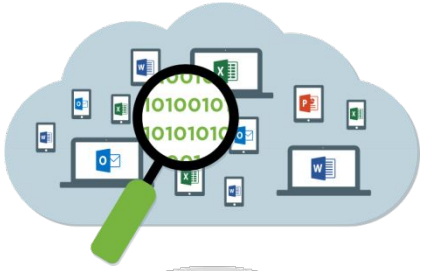
- **Semester 1** (4 weeks): 8 lectures, 8 practical classes (2 Labs) → exam



Don’t forget about 40 academic hours (45 min) of homework

- **Semester 2** : 16 practical classes (4 Labs)→ credit test

Information and computer sciences



Information science is primarily concerned with gathering, storing, transmitting, sharing and protecting all forms of information.

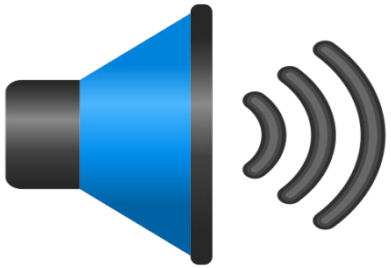
Computer science is the study of processes that interact with data and that can be represented as data in the form of programs. It enables the use of algorithms to manipulate, store, and communicate digital information.

Information technology (IT) is the practical use of computers and computer networks to store, retrieve, transmit, and manipulate data. It includes computer hardware, software, electronics, internet services, telecommunication equipment.

Information vs Data

Information can be thought of as the resolution of uncertainty. When you get some information you decrease the level of uncertainty. Information is related to knowledge which is awareness or understanding of something.

In communication systems all information to be transmitted and received must be expressed in a convenient form called a ***message*** (numbers and text symbols, sound, image). Information is the content of a message. A ***signal*** is a physical process representing a message (electromagnetic waves, electrical current, optical emission, acoustic waves).



The word "data" was first used to mean "transmissible and storable computer information" in 1946. ***Data*** are individual units of information, an array of values in some context. *Raw data* is a collection of numbers or characters before being processed. An analog device treats a datum as a voltage, position, or other physical quantity. Digital computers operate with sequence of symbols (typically "0" and "1").

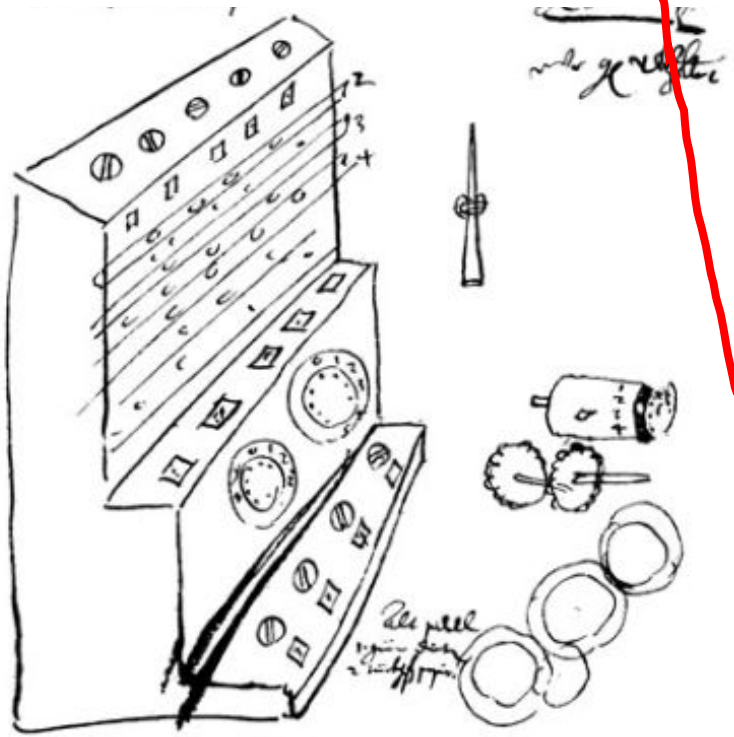
Data only becomes information suitable for making decisions once it has been processed and someway analyzed

Knowledge is power. Who owns information, he owns the world. Data is the new oil of the digital economy.

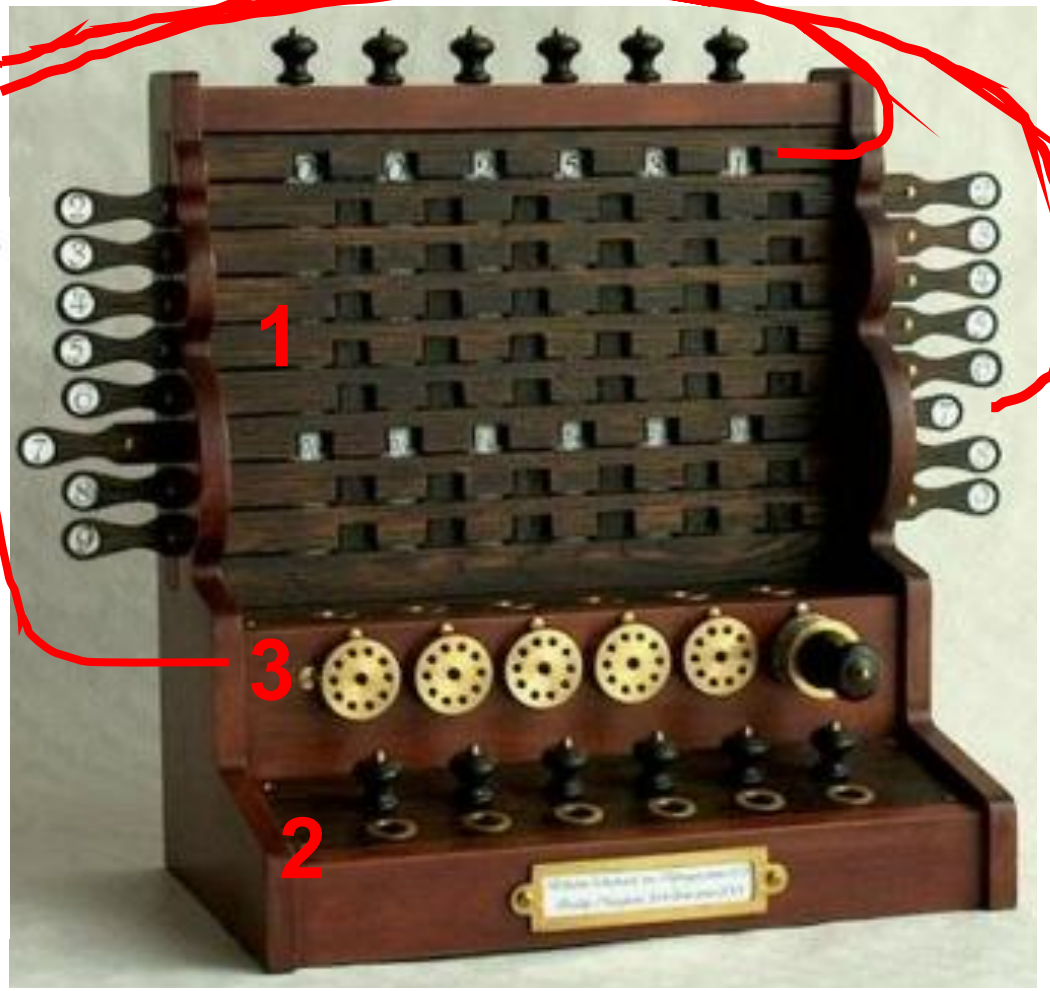
History of computer engineering

Add the results for each multiplication

Enter the 2nd multiplier

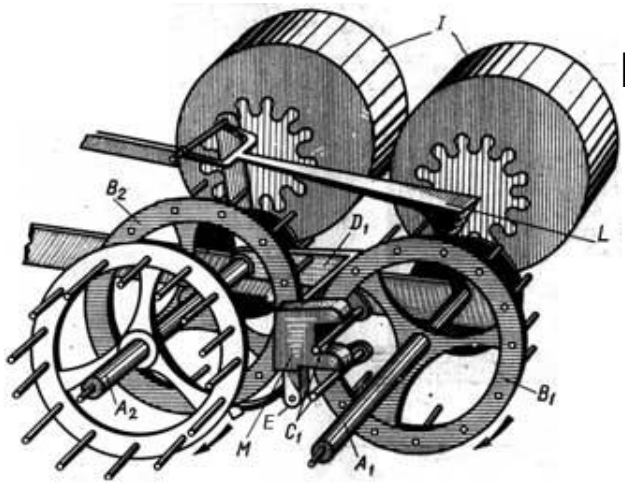


The world's 1st mechanical calculating machine designed by Wilhelm Schickard (1623)



Replica of Schickard's calculating machine

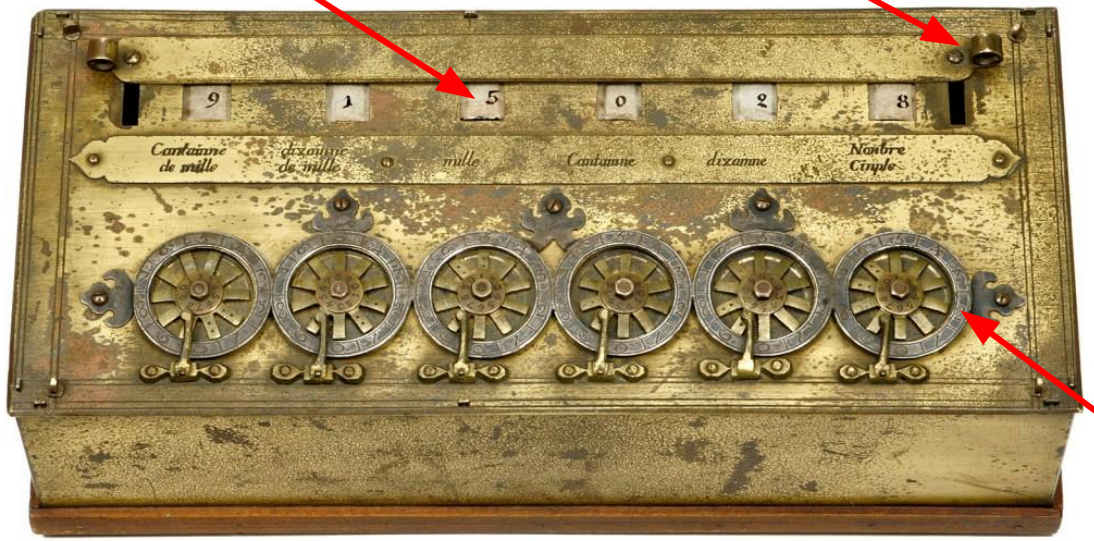
Mechanical arithmetic machines



Pascaline is Blaise Pascal's mechanical arithmetic machine (1642)

Windows for results

The covering plank

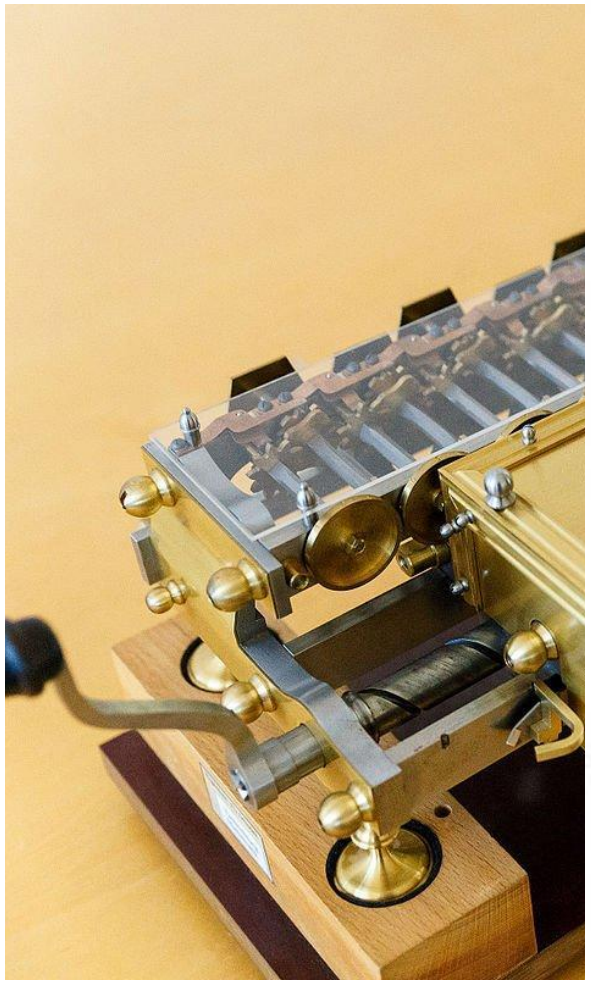


Wheels for setting digits

Mechanical arithmetic machines

The adding machine of Samuel Morland (1666)

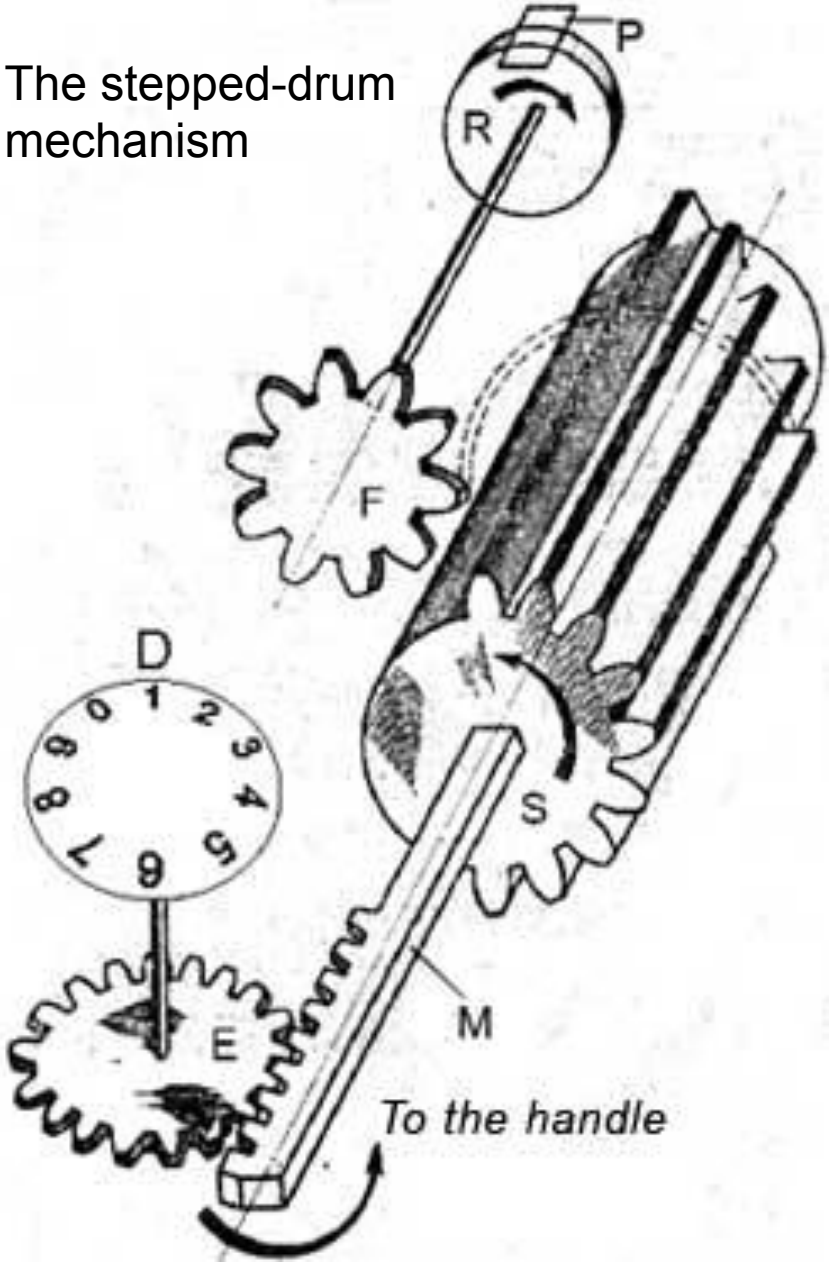
Compact size (122 x 71 x 8 mm)



Replica of Stepped Reckoner of Gottfried Leibniz (1673)

67 cm long, 27 wide and 17 cm high

The stepped-drum mechanism



Mechanical computers

The ap… …ted
with th… …age

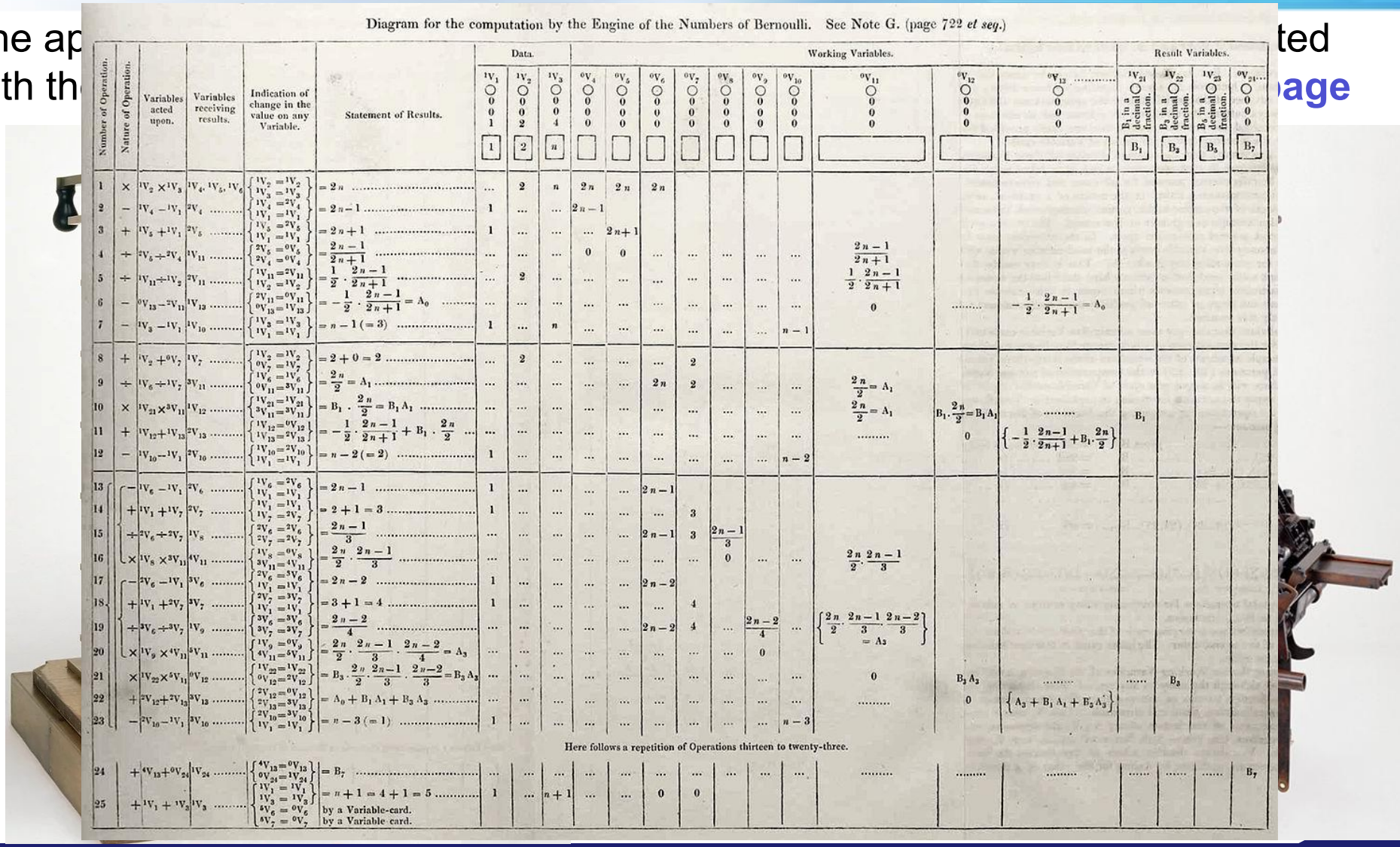
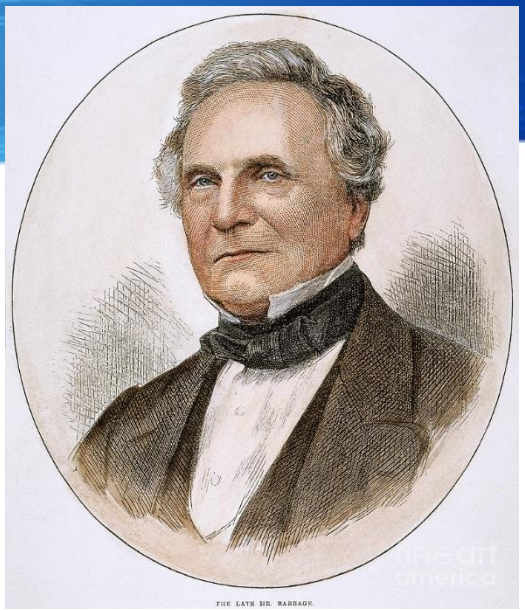


Diagram for the computation by the Engine of the Numbers of Bernoulli. See Note G. (page 722 *et seq.*)

Number of Operation.	Nature of Operation.	Variables acted upon.	Variables receiving results.	Indication of change in the value on any Variable.	Statement of Results.	Data. ${}^1V_1$ (1)	Data. ${}^1V_2$ (2)	Data. ${}^1V_3$ (n)	Working Variables. ${}^0V_4$	${}^0V_5$	${}^0V_6$	${}^0V_7$	${}^0V_8$	${}^0V_9$	${}^0V_{10}$	${}^0V_{11}$	${}^0V_{12}$	${}^0V_{13}$	Result Variables. ${}^1V_{21}$ B_1 in a decimal fraction.	${}^1V_{22}$ B_3 in a decimal fraction.	${}^1V_{23}$ B_5 in a decimal fraction.	${}^0V_{24}$ .....
1	×	${}^1V_2 \times {}^1V_3$	${}^1V_4, {}^1V_5, {}^1V_6$	${}^1V_2 = {}^1V_2$; ${}^1V_3 = {}^1V_3$	$= 2n$	...	2	n	$2n$	$2n$	$2n$											
2	−	${}^1V_4 - {}^1V_1$	${}^2V_4$	${}^1V_4 = {}^2V_4$; ${}^1V_1 = {}^1V_1$	$= 2n-1$	1	...	...	$2n-1$													
3	+	${}^1V_5 + {}^1V_1$	${}^2V_5$	${}^1V_5 = {}^2V_5$; ${}^1V_1 = {}^1V_1$	$= 2n+1$	1	...	...	...	$2n+1$												
4	÷	${}^2V_5 \div {}^2V_4$	${}^1V_{11}$	${}^2V_5 = {}^0V_5$; ${}^2V_4 = {}^0V_4$	$= \frac{2n-1}{2n+1}$	...	...	...	0	0	...	...	...	...	...	$\frac{2n-1}{2n+1}$						
5	÷	${}^1V_{11} \div {}^1V_2$	${}^2V_{11}$	${}^1V_{11} = {}^2V_{11}$; ${}^1V_2 = {}^1V_2$	$= \frac{1}{2} \cdot \frac{2n-1}{2n+1}$	...	2	...	...	...	...	...	...	...	...	$\frac{1}{2} \cdot \frac{2n-1}{2n+1}$						
6	−	${}^0V_{13} - {}^2V_{11}$	${}^1V_{13}$	${}^2V_{11} = {}^0V_{11}$; ${}^0V_{13} = {}^1V_{13}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$	...	...	...	...	...	...	...	...	...	...	0	.....	$-\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$				
7	−	${}^1V_3 - {}^1V_1$	${}^1V_{10}$	${}^1V_3 = {}^1V_3$; ${}^1V_1 = {}^1V_1$	$= n-1\ (=3)$	1	...	n	...	...	...	...	...	...	$n-1$							
8	+	${}^1V_2 + {}^0V_7$	${}^1V_7$	${}^1V_2 = {}^1V_2$; ${}^0V_7 = {}^1V_7$	$= 2+0=2$	...	2	...	...	...	...	2										
9	÷	${}^1V_6 \div {}^1V_7$	${}^3V_{11}$	${}^1V_6 = {}^1V_6$; ${}^0V_{11} = {}^3V_{11}$	$= \frac{2n}{2} = A_1$	...	...	...	...	...	$2n$	2	...	...	...	$\frac{2n}{2} = A_1$						
10	×	${}^1V_{21} \times {}^3V_{11}$	${}^1V_{12}$	${}^1V_{21} = {}^1V_{21}$; ${}^3V_{11} = {}^3V_{11}$	$= B_1 \cdot \frac{2n}{2} = B_1 A_1$	...	...	...	...	...	...	...	...	...	...	$\frac{2n}{2} = A_1$	$B_1 \cdot \frac{2n}{2} = B_1 A_1$	.....	B_1			
11	+	${}^1V_{12} + {}^1V_{13}$	${}^2V_{13}$	${}^1V_{12} = {}^0V_{12}$; ${}^1V_{13} = {}^2V_{13}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}$ ...	...	...	...	...	...	...	...	...	...	...	.....	0	$\left\{-\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}\right\}$				
12	−	${}^1V_{10} - {}^1V_1$	${}^2V_{10}$	${}^1V_{10} = {}^2V_{10}$; ${}^1V_1 = {}^1V_1$	$= n-2\ (=2)$	1	...	...	...	...	...	...	...	...	$n-2$							
13	−	${}^1V_6 - {}^1V_1$	${}^2V_6$	${}^1V_6 = {}^2V_6$; ${}^1V_1 = {}^1V_1$	$= 2n-1$	1	...	...	...	...	$2n-1$											
14	+	${}^1V_1 + {}^1V_7$	${}^2V_7$	${}^1V_1 = {}^1V_1$; ${}^1V_7 = {}^2V_7$	$= 2+1=3$	1	...	...	...	...	...	3										
15	÷	${}^2V_6 \div {}^2V_7$	${}^1V_8$	${}^2V_6 = {}^2V_6$; ${}^2V_7 = {}^2V_7$	$= \frac{2n-1}{3}$	...	...	...	...	...	$2n-1$	3	$\frac{2n-1}{3}$									
16	×	${}^1V_8 \times {}^3V_{11}$	${}^4V_{11}$	${}^1V_8 = {}^0V_8$; ${}^3V_{11} = {}^4V_{11}$	$= \frac{2n}{2} \cdot \frac{2n-1}{3}$	...	...	...	...	...	...	...	0	...	...	$\frac{2n}{2} \cdot \frac{2n-1}{3}$						
17	−	${}^2V_6 - {}^1V_1$	${}^3V_6$	${}^2V_6 = {}^3V_6$; ${}^1V_1 = {}^1V_1$	$= 2n-2$	1	...	...	...	...	$2n-2$											
18	+	${}^1V_1 + {}^2V_7$	${}^3V_7$	${}^2V_7 = {}^3V_7$; ${}^1V_1 = {}^1V_1$	$= 3+1=4$	1	...	...	...	...	...	4										
19	÷	${}^3V_6 \div {}^3V_7$	${}^1V_9$	${}^3V_6 = {}^3V_6$; ${}^3V_7 = {}^3V_7$	$= \frac{2n-2}{4}$	...	...	...	...	...	$2n-2$	4	...	$\frac{2n-2}{4}$	...							
20	×	${}^1V_9 \times {}^4V_{11}$	${}^5V_{11}$	${}^1V_9 = {}^0V_9$; ${}^4V_{11} = {}^5V_{11}$	$= \frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{4} = A_3$ ...	...	...	...	...	...	...	...	...	0	...			$\left\{\frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{3} = A_3\right\}$				
21	×	${}^1V_{22} \times {}^5V_{11}$	${}^0V_{12}$	${}^1V_{22} = {}^0V_{12}$; ${}^2V_{12} = {}^2V_{12}$	$= B_3 \cdot \frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{3} = B_3 A_3$ ...	...	...	...	...	...	...	...	...	...	...	0	$B_3 A_3$	.....	.....	B_3		
22	+	${}^2V_{12} + {}^2V_{13}$	${}^3V_{13}$	${}^2V_{12} = {}^0V_{12}$; ${}^2V_{13} = {}^3V_{13}$	$= A_0 + B_1 A_1 + B_3 A_3$	...	...	...	...	...	...	...	...	...	...	.....	0	$\{A_3 + B_1 A_1 + B_3 A_3\}$				
23	−	${}^2V_{10} - {}^1V_1$	${}^3V_{10}$	${}^2V_{10} = {}^3V_{10}$; ${}^1V_1 = {}^1V_1$	$= n-3\ (=1)$	1	...	...	...	...	...	...	...	...	$n-3$							

Here follows a repetition of Operations thirteen to twenty-three.

24	+	${}^4V_{13} + {}^0V_{24}$	${}^1V_{24}$	${}^4V_{13} = {}^0V_{13}$; ${}^0V_{24} = {}^1V_{24}$	$= B_7$	...	...	...	...	...	...	...	...	...	...	.....	.....	.....	.....	.....	.....	B_7
25	+	${}^1V_1 + {}^1V_3$	${}^1V_3$	${}^1V_1 = {}^1V_1$; ${}^1V_3 = {}^1V_3$; ${}^8V_6 = {}^0V_6$ by a Variable-card. ; ${}^8V_7 = {}^0V_7$ by a Variable card.	$= n+1 = 4+1=5$	1	...	$n+1$	...	...	0	0										



Charles Babbage
Ada Lovelace

The Difference engine (1819 – 1822) Analytical Engine (1834 – 1848)

Mechanical computers

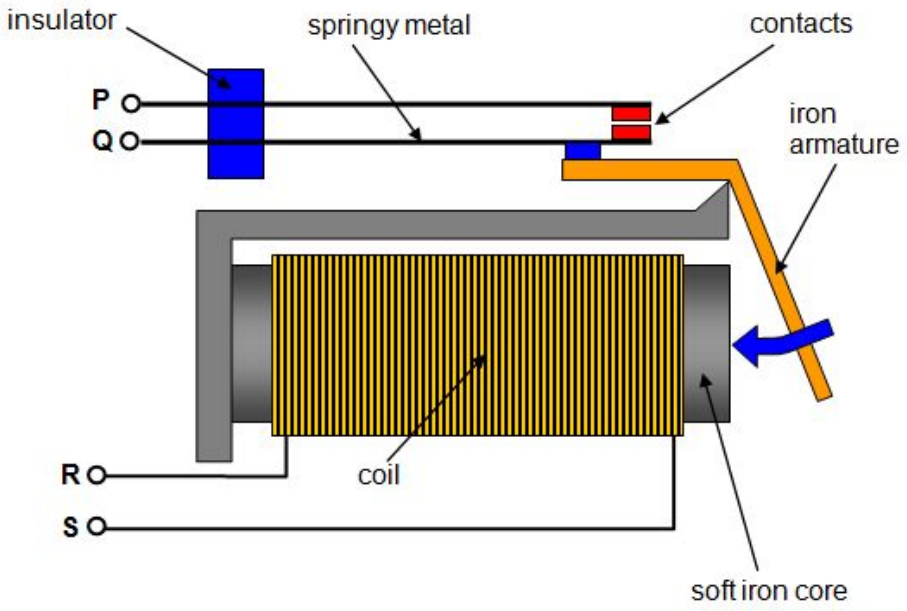
After Babbage, a significant contribution to the development of computer technology was made by the American inventor **Herman Hollerith.** In 1890, he first created a manual puncher for applying digital data to punch cards. His machine (called a tabulator) felt holes on punch cards and perceived them as numbers.

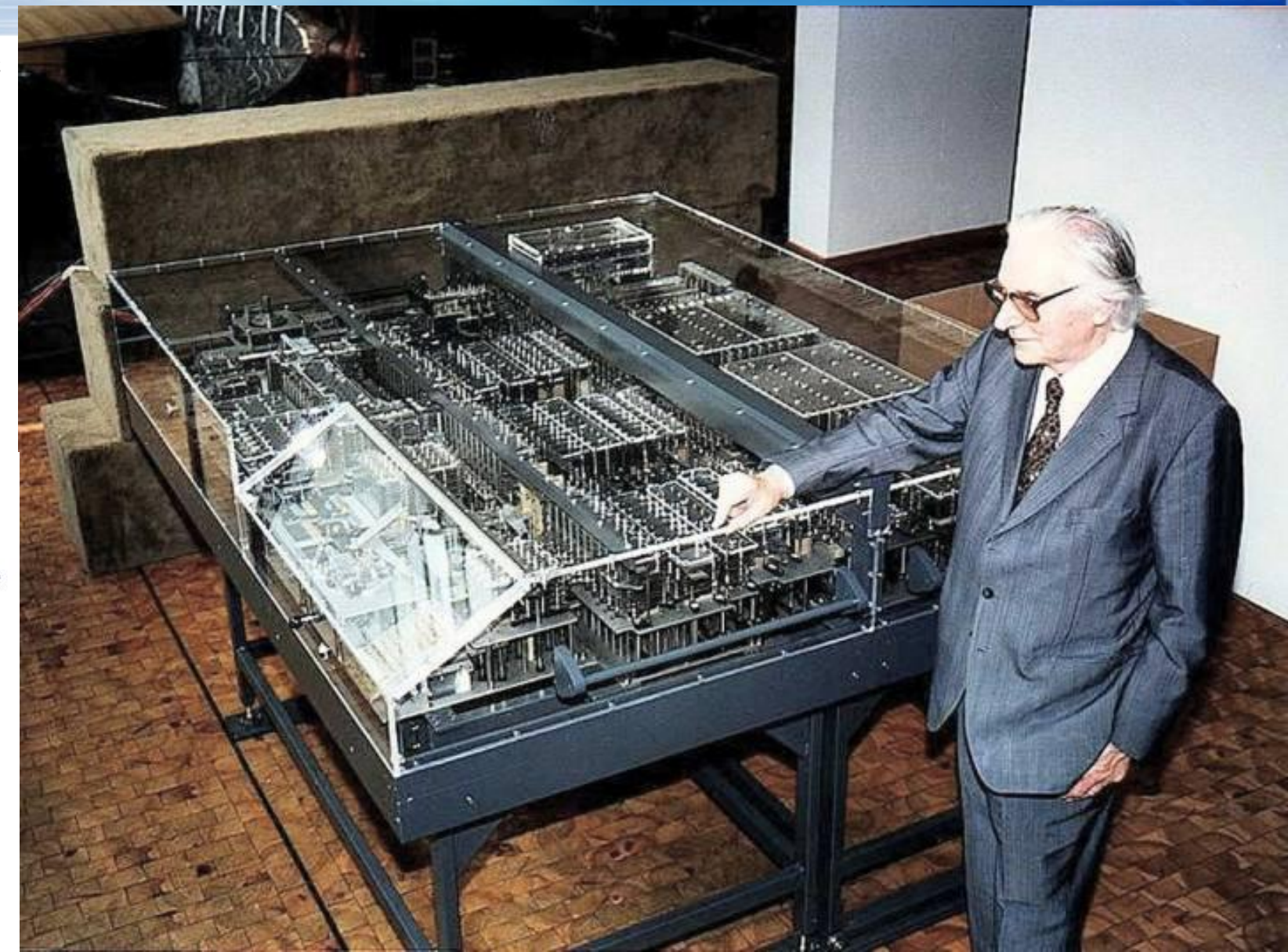
Hollerith tabulators were used in censuses in the USA, Austria, Canada, and Norway. It was also applied during the first All-Russian population census in 1897.

In 1896, Hollerith founded the world-famous company Computer Tabulating Recording, specializing in the production of punching machines and punch cards. Subsequently, the company was transformed into International Business Machines (IBM), which became an advanced computer developer.

Mechanical computers

The first creator of an automatic computer (Z1) is the German scientist **Conrad Zuse**. In the device introduced by Zuze in 1936, there were used a binary number system (rather than a decimal), floating-point numbers, a three-address programming system and punch card. The basic elements were electromagnetic relays:





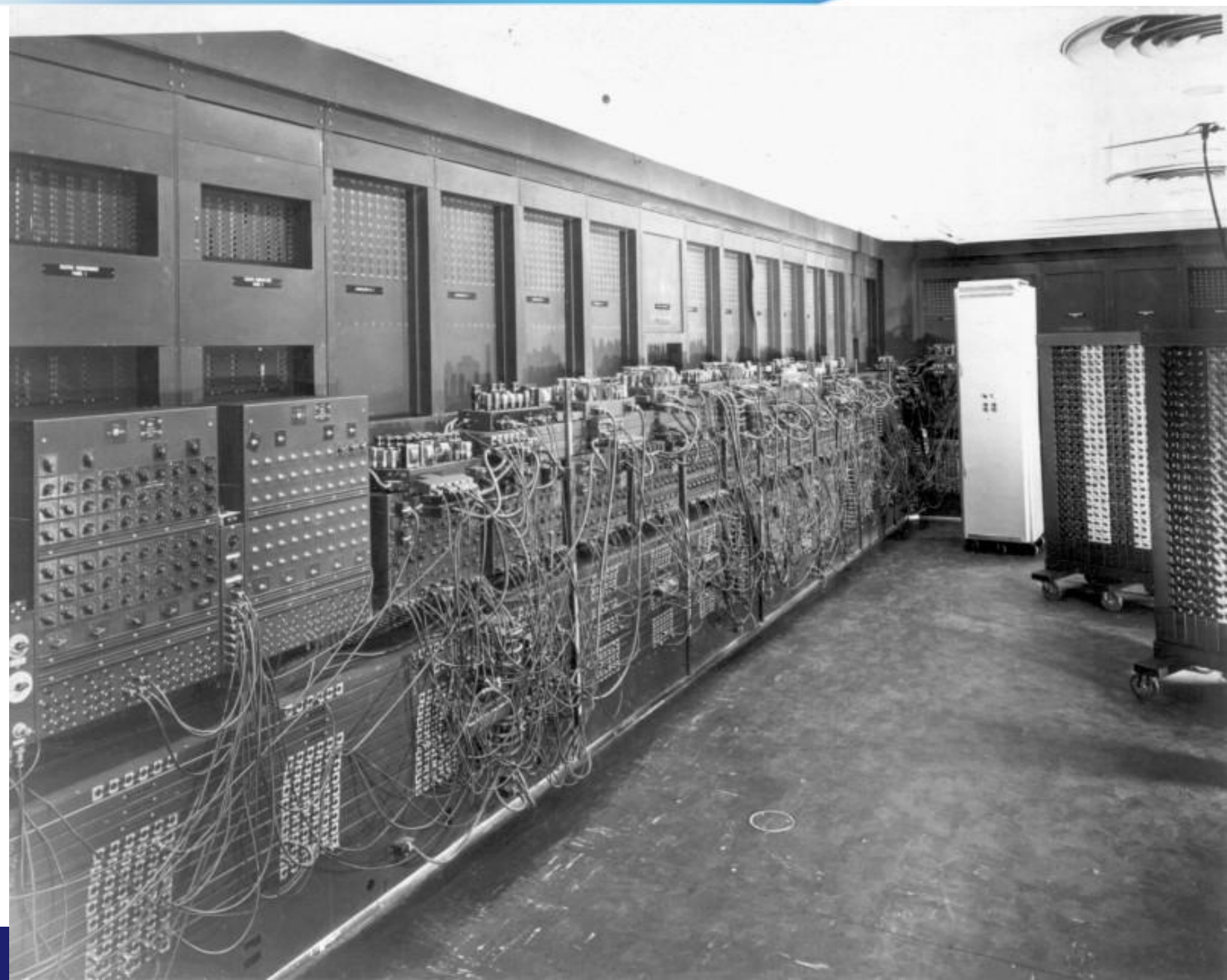
The first generation of electronic computers

An electronic computer is a hardware and software computing device that operates using electronic components and performs the actions specified by its programs.

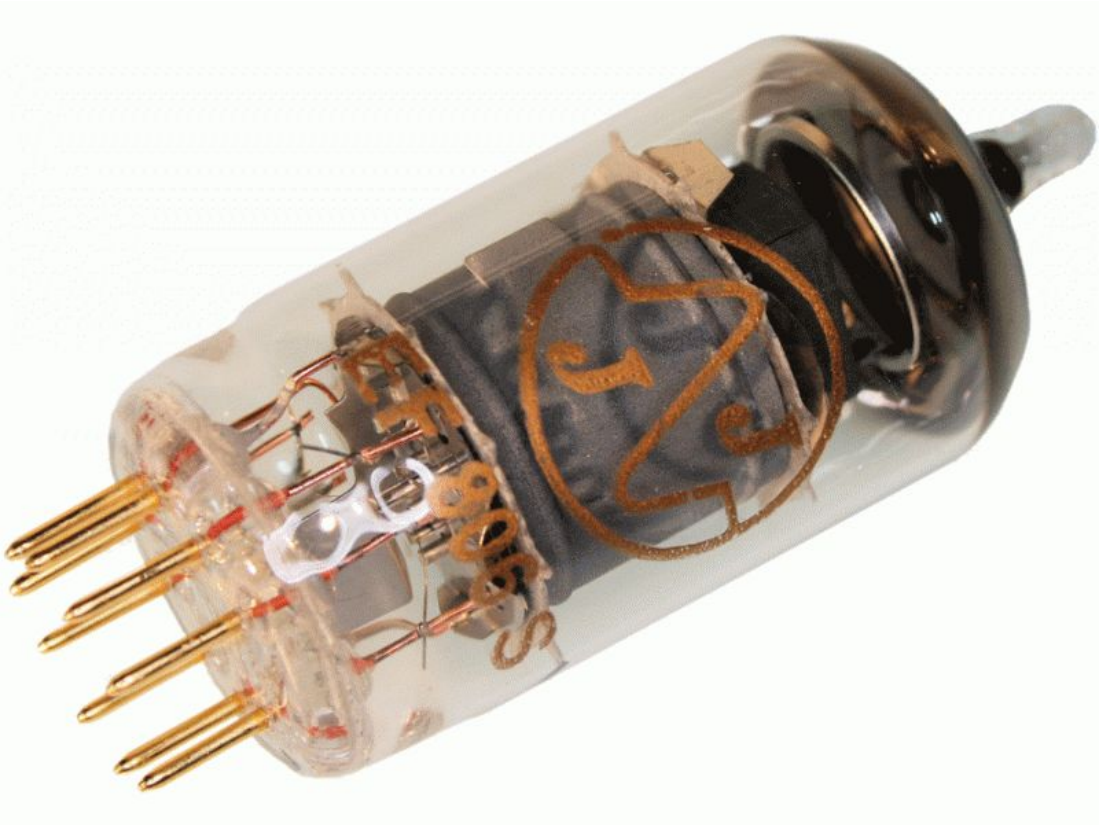
The first universal electronic computer was built with the use of electronic tubes, it was created in the United States in 1945. The new machine is called "Electronic Numerical Integrator and Computer" (**ENIAC**). The designers of ENIAC were John Mauchly and John Eckert.

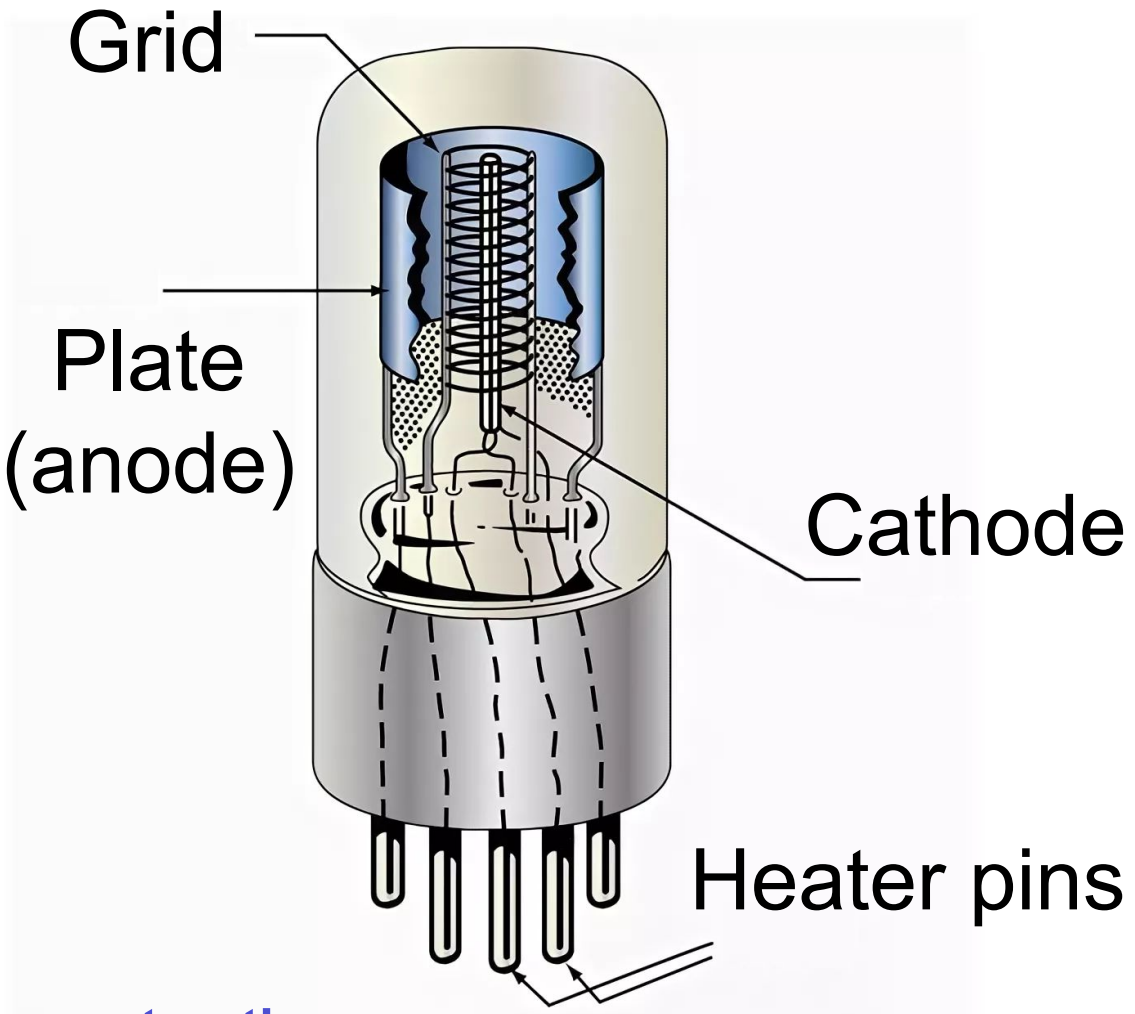
It had a speed on the order of 1000 times faster than that of electro-mechanical computers.

This computer with 18 000 electronic lamps occupied a room measuring 90 by 15 meters. The weight of the machine was 27 tons and the power consumption was 150 kW. ENIAC worked at a clock frequency of 100 kHz and performed addition in 0.2 ms, and multiplication in 2.8 ms.



The first generation of electronic computers



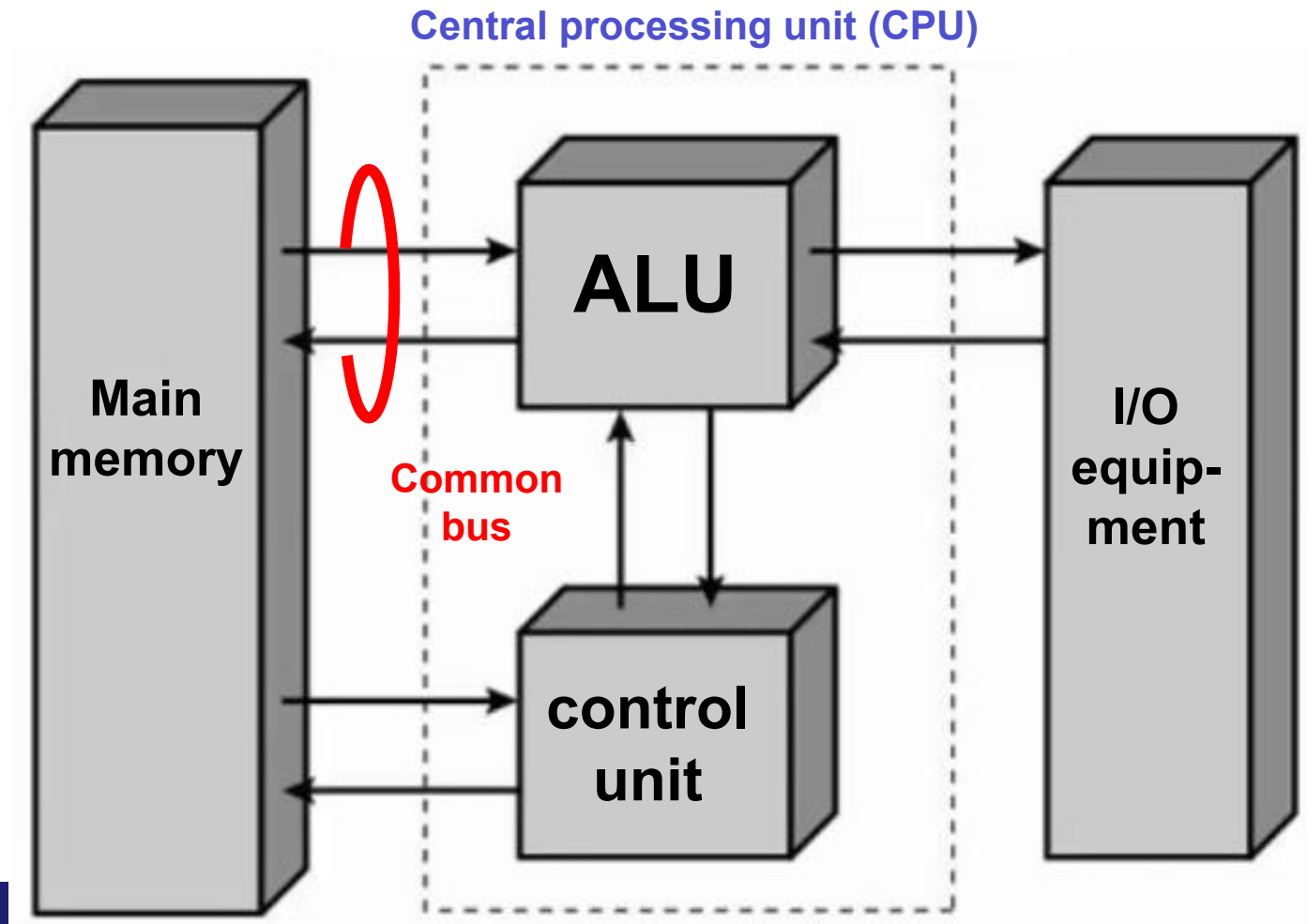


Electron (vacuum) tube construction

John von Neumann's computer architecture (1945)

John von Neumann

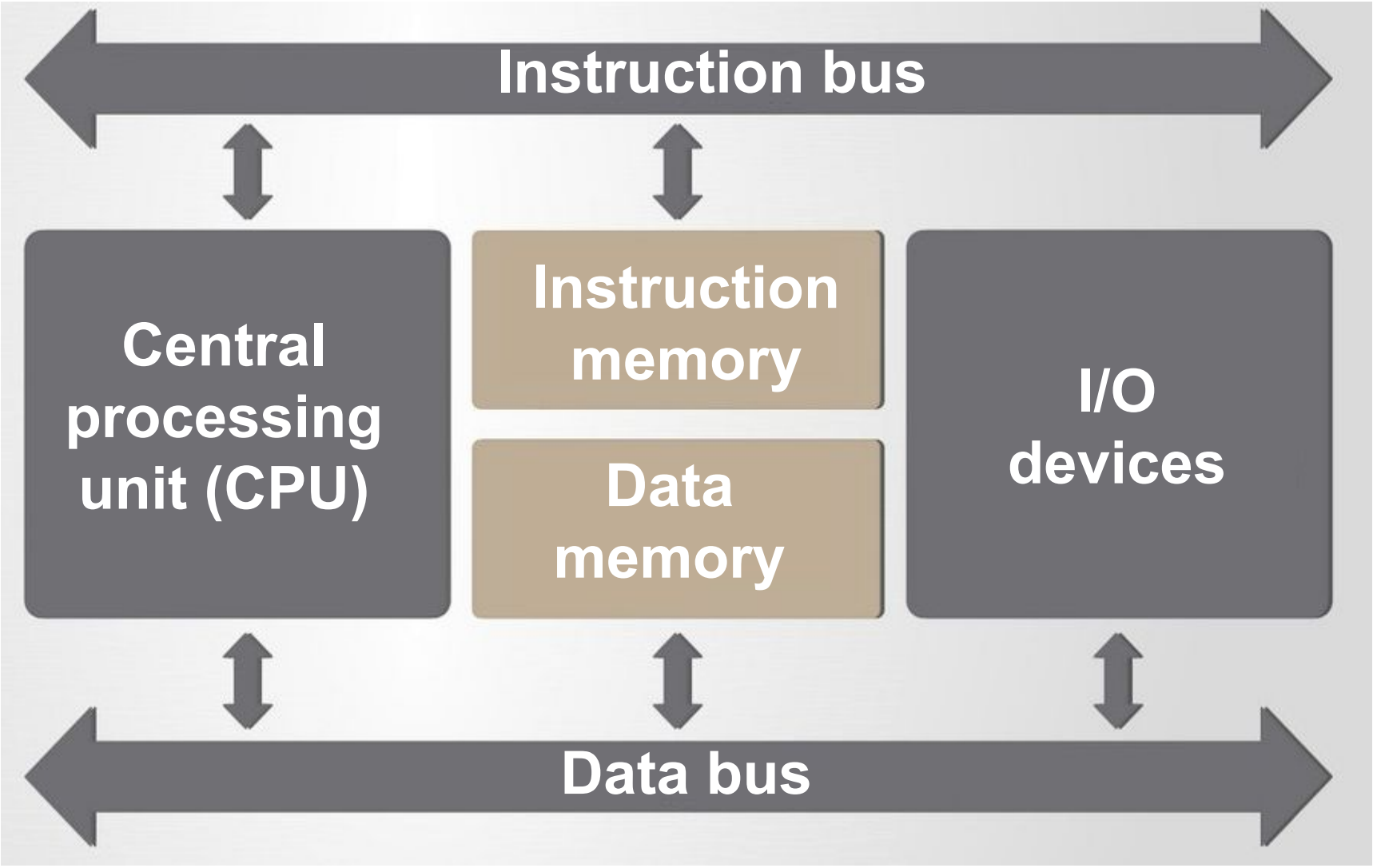
Computer architecture is a set of rules and methods that describe the functionality, organization, and implementation of computer systems.



The von Neumann architecture of stored programs consist of:

1. A main memory which stores both data and instructions
2. An arithmetic-logical unit (ALU) capable of operating on binary data
3. A program control unit which interprets the instructions in memory and causes them to be executed
4. Input and output (I/O) equipment operated by the control unit

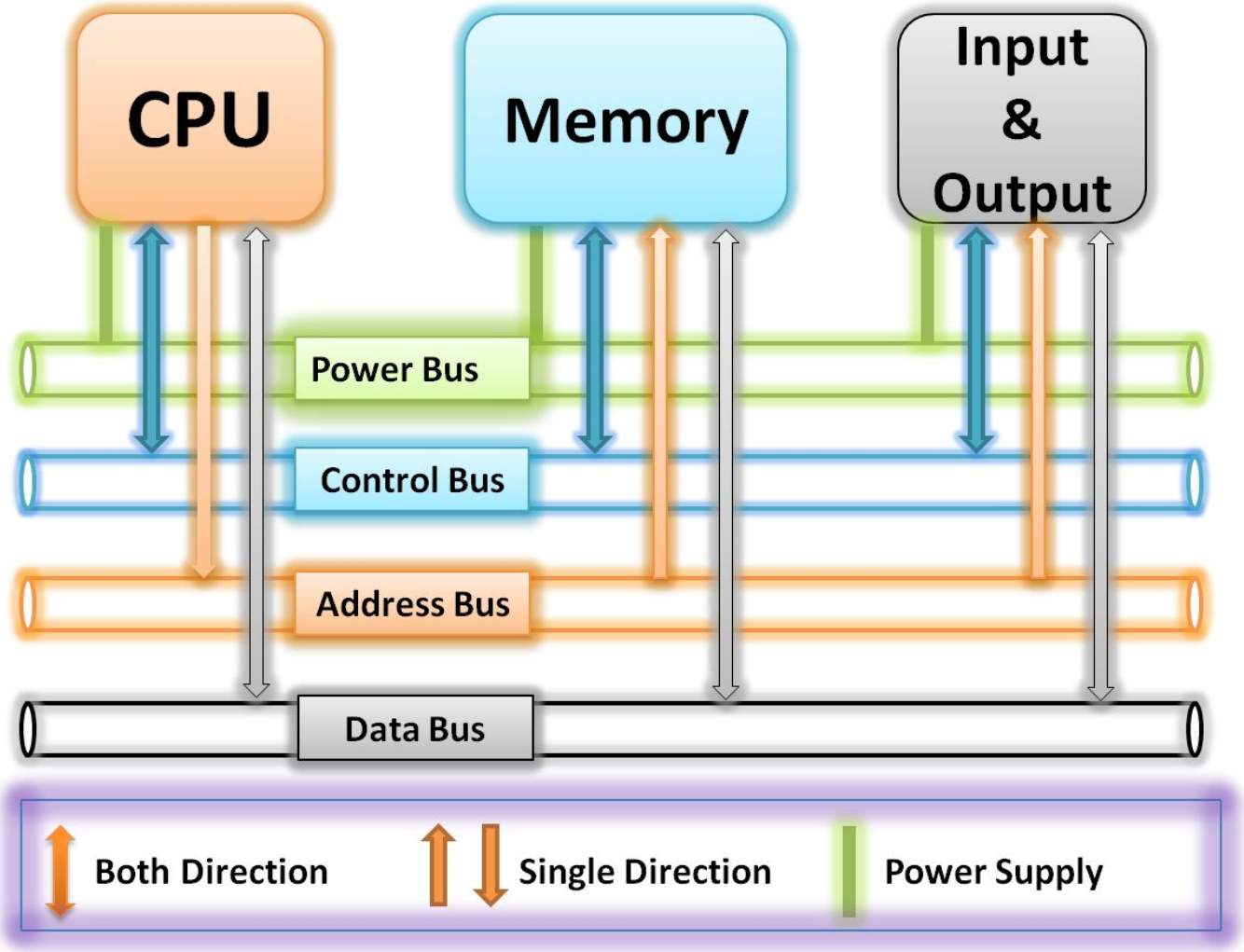
Harvard architecture of computers



It contrast with the von Neumann architecture the Harvard architecture uses the physically separated storage and signal pathways (buses) for instructions and data.

The term originated from the “Automatic Sequence Controlled Calculator (ASCC, also called Mark I)” designed by Harvard University’s staff.

System bus structure



Data Bus is used to transfer data from one of the computer component to another.

Address Bus is used to identify the computer component for data sending.

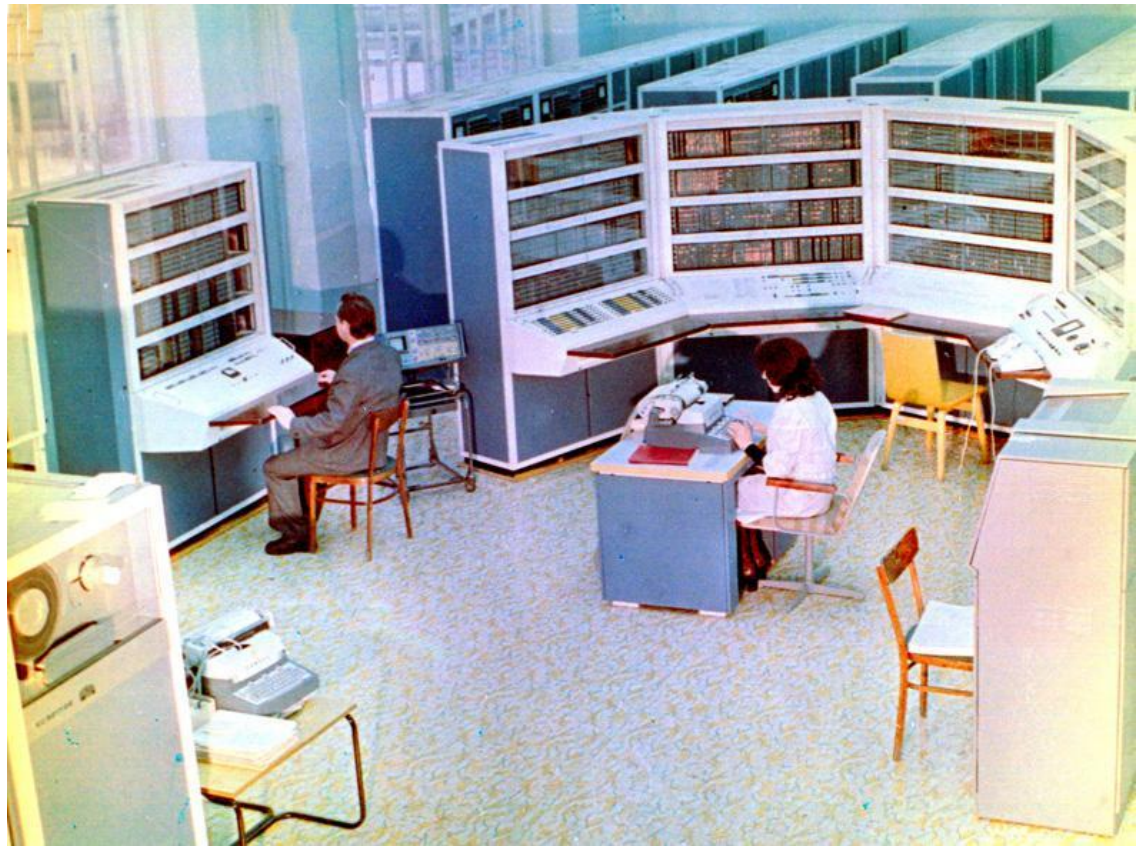
Control Bus is used to control signals from one component to another.

Basic computer components:

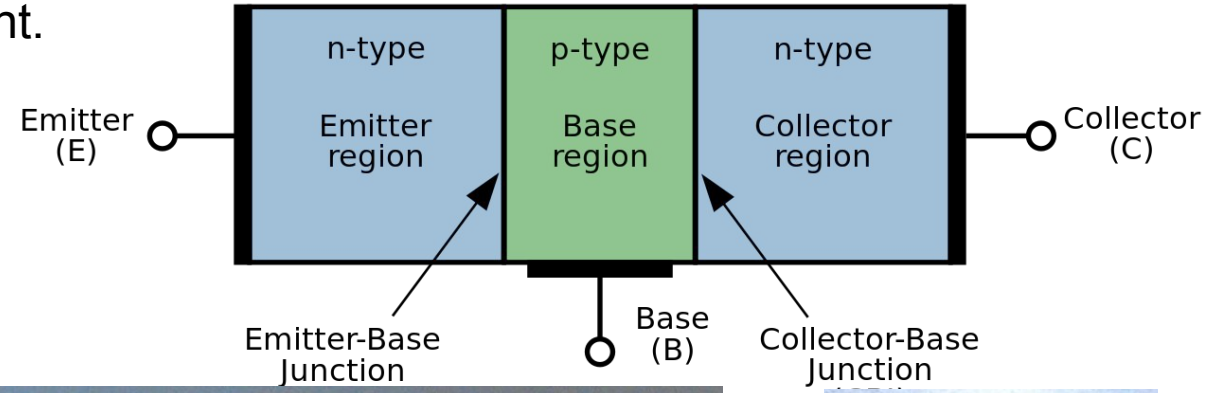
- Motherboard (baseboard)
- Central processing unit (CPU)
- Random access memory (RAM)
- Graphical processing unit (GPU)
- non-volatile memory devices (hard disk drive HDD, solid-state drive SSD).

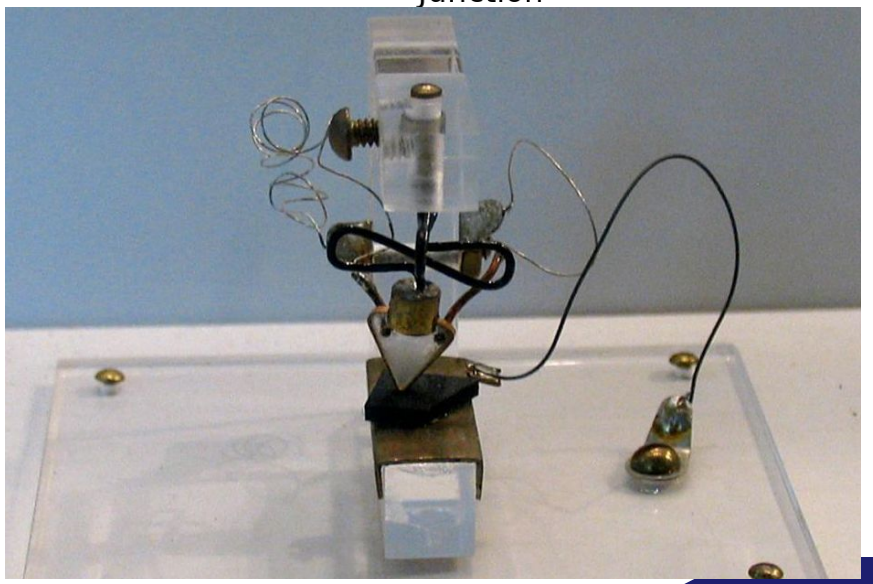
The second generation of computers (1953)

In the 1960s, transistors became the elemental base for second-generation computers. The use of semiconductor elements significantly improved the quality of computers in all respects: they became more compact, reliable, less energy-consuming and more efficient.



USSR transistor-based computer “БЭСМ-6” (1966)

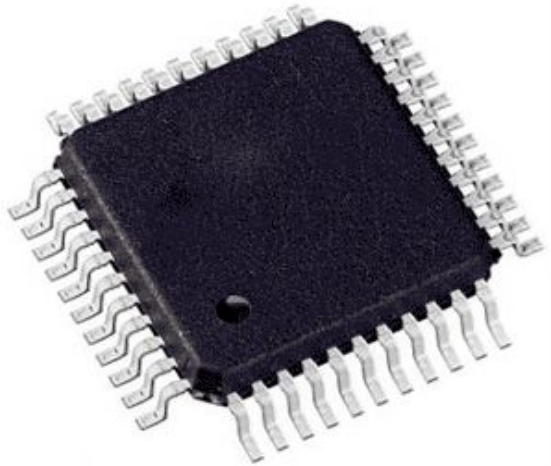




The first transistor model

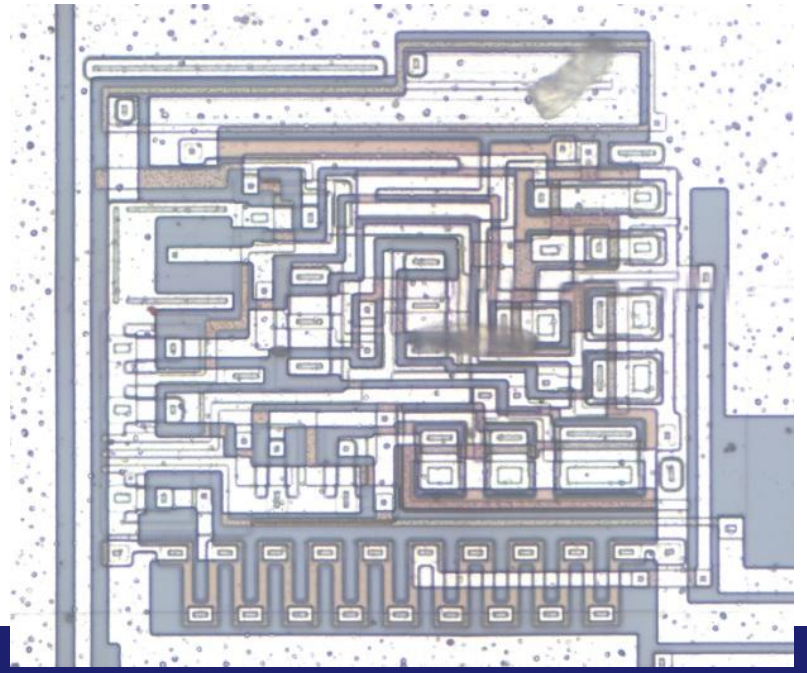
The third generation (1960s)

An **integrated circuit** (microchip) is a set of electronic circuits on one small flat piece of semiconductor material (normally silicon). The integration of large numbers of tiny transistors into a small chip results in circuits that are orders of magnitude smaller, faster, and less expensive.

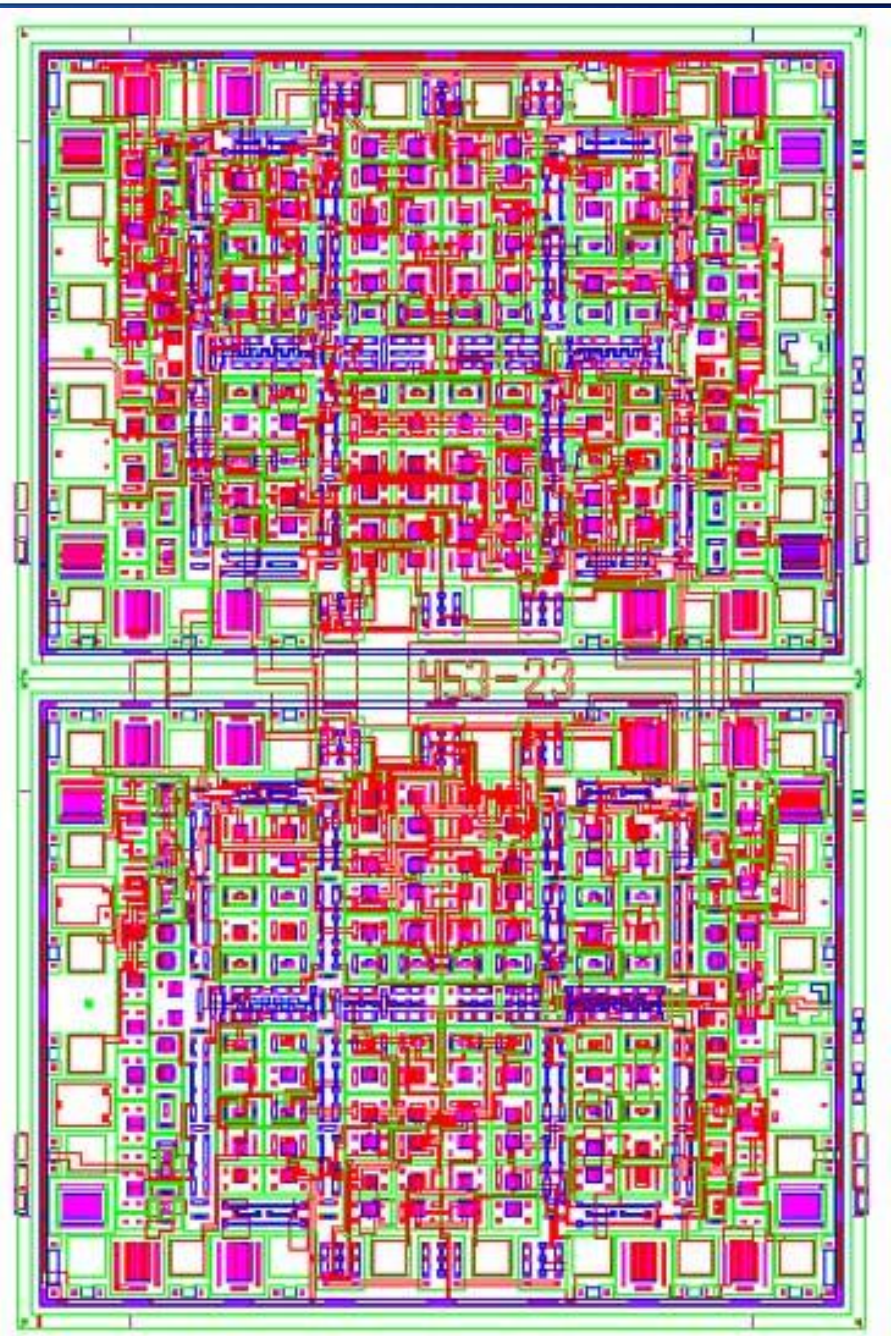


The first integrated circuit was produced in September 1958, and computers using them began to appear in the early 1960s.

An early commercial use was the 1965. The integrated circuit enabled the development of much smaller computers.



integrated circuit structure



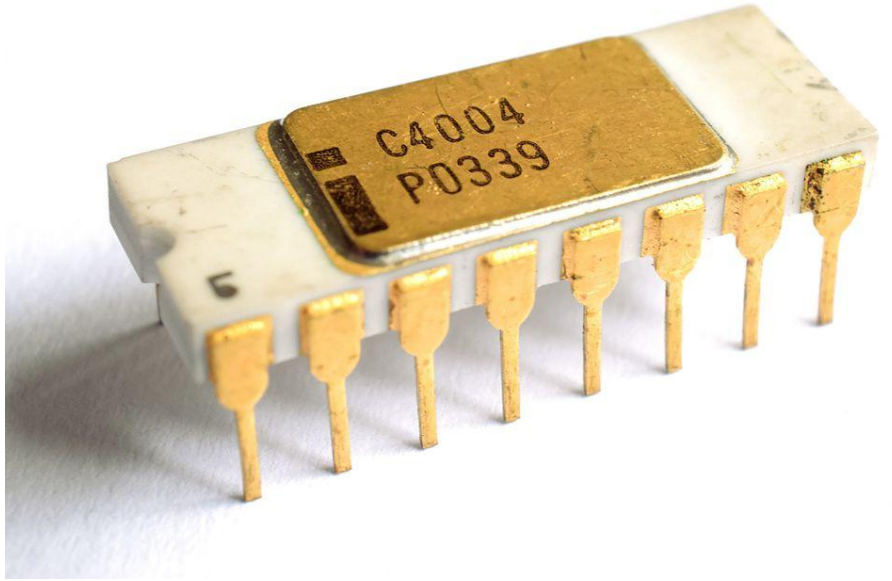
The fourth generation (1970s)

The development of microelectronics has led to the creation of the ability to place thousands of integrated circuits on a single chip. The era of microcomputers has begun.

In 1980, the central processor of a small computer was possible to place on a chip area of only a quarter square inch (1.61 cm^2).

The crystal thickness of the first Intel processor was 10 microns. In the first Intel processor i4004 released in 1971 there were 2300 transistors on one chip. And in the Intel Pentium 4 processor, released on April 14, 2003 there were already 55 million of them.

Intel - i4004 (1971)

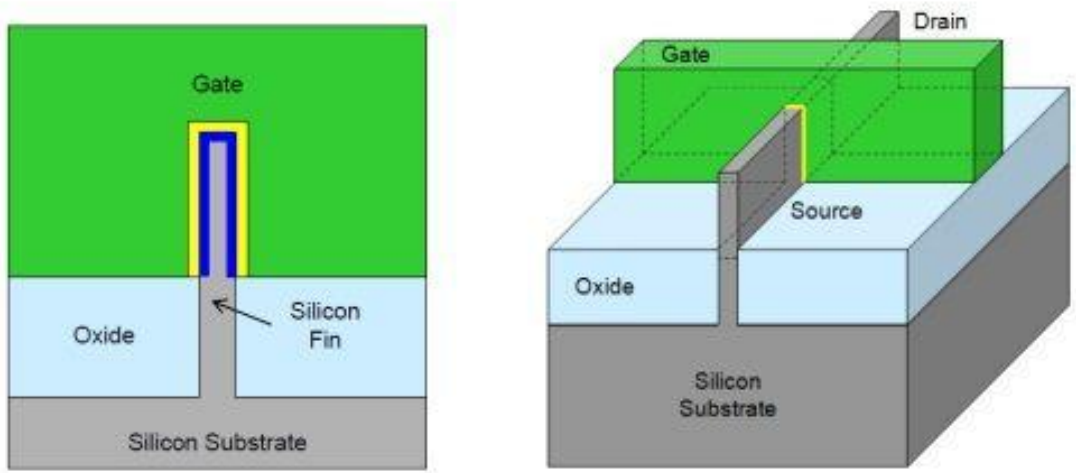


What is the speed of modern microcomputers? It is 10 times faster than the performance of third-generation computers on integrated circuits, 1000 times faster than second-generation computers with transistors and 100,000 times faster than first-generation computers with electronic lamps.

The fourth generation of computers

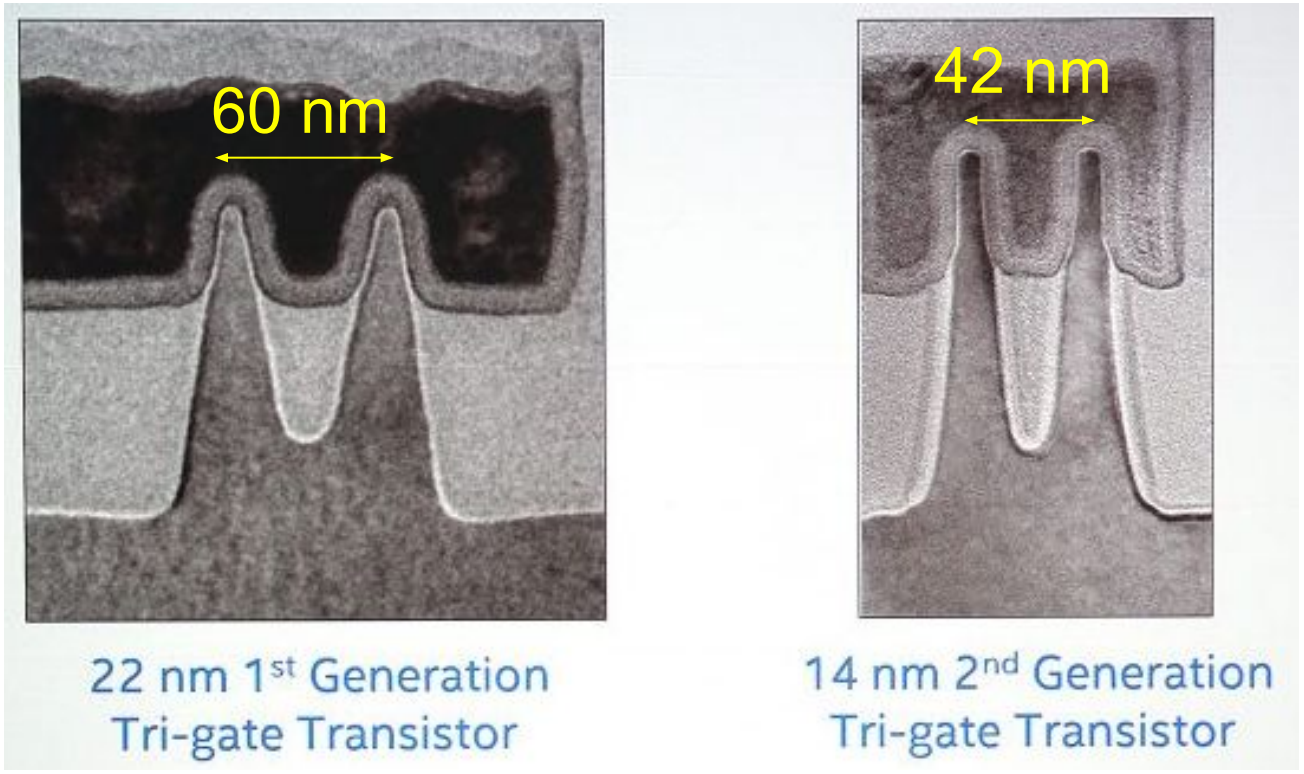
Semiconductor device fabrication (technological process) is the process used to manufacture semiconductor devices. In the electronic industry, in the common sense, this is a value that indicates the resolution of the equipment used in the manufacture of chips. In other words how small we can get the parts of basic elements. In modern semiconductor manufacturing photolithography is the most common.

Fully Depleted Tri-Gate Transistor



32 nm – 2009
22 nm – 2012
14 nm – 2014

10 nm – 2016
7 nm – 2018
5 nm – 2019



Central processing unit

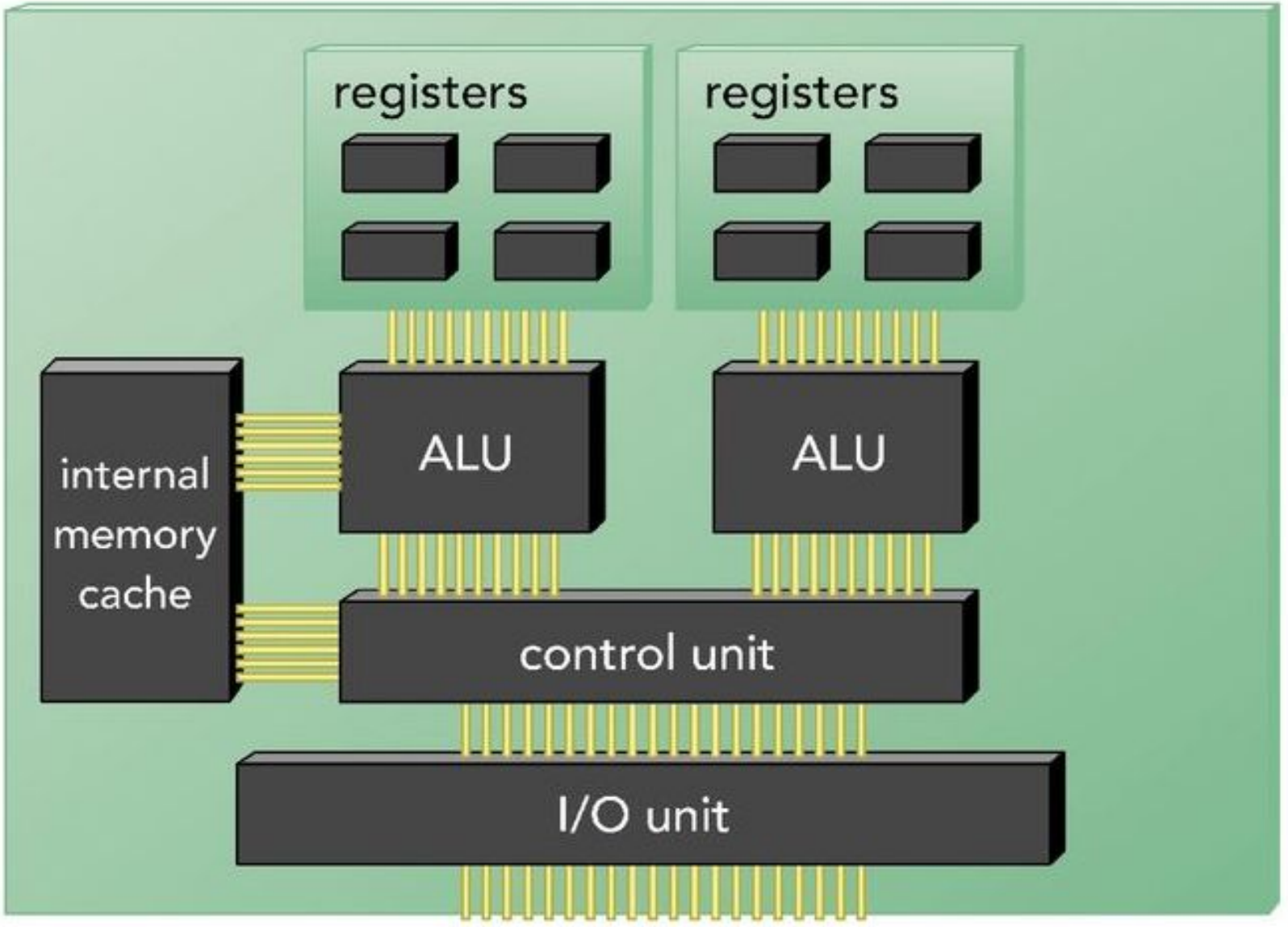
ALU is a digital circuit within the processor that performs integer arithmetic and bitwise logic operations.

Registers and CPU cache is super-operative memory working with processor speed, ALU works with them.

Control unit manage operations of all CPU nodes by generating and transmitting to its other components control pulses coming from a quartz clock generator.

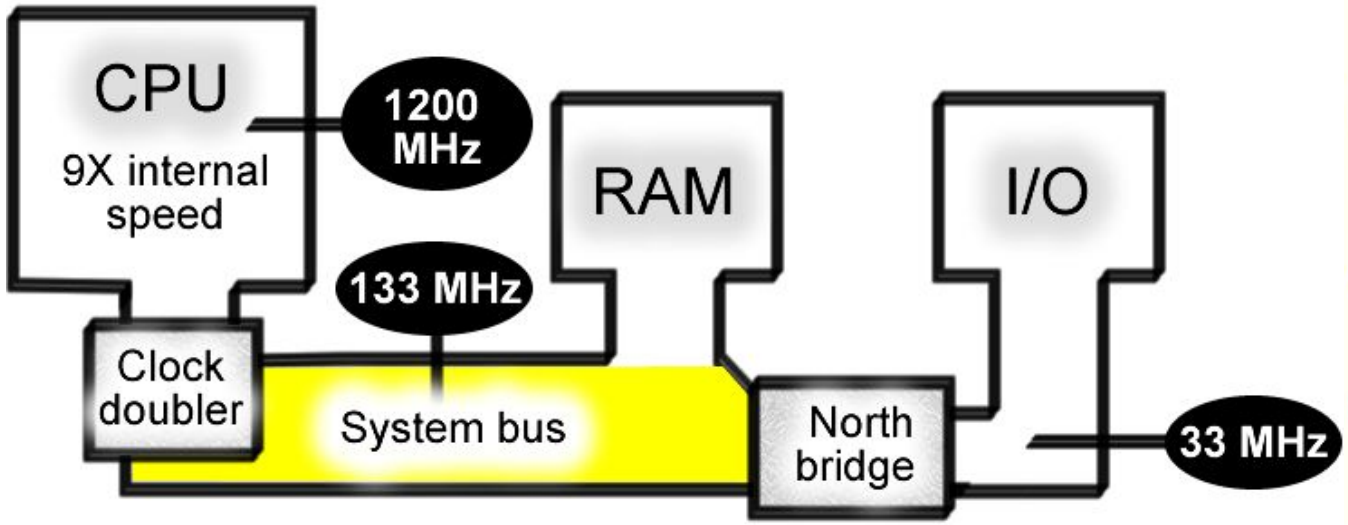
Main CPU characteristics :

1. The clock frequency
2. Capacity
3. Cache size
4. Fabrication process
5. Socket



Central processing unit

The clock frequency (clock rate) is the number of operations that the processor can perform per second. The unit of measurement is MHz and GHz (megahertz and gigahertz). 1 MHz means that the processor can perform 1 million operations per second, if the processor is 3.16 GHz it can perform 3 Billion 166 million operations in 1 second. There are two types of clock speed – internal (System Clock) and external (Bus Clock).



- System Clock rate is the clock frequency with which the work occurs inside the processor.
- Bus Clock rate is clock speed *of* bus. Just like the processor, manufacturers state the clock speed for a bus in hertz. Recall that one megahertz (MHz) is equal to one million ticks per second. Today's processors usually have a bus clock speed of 533, 667, 800, 1066, 1333, 1600, 2666, or 3200 MHz. The higher the bus clock speed, the faster the transmission of data, which results in programs running faster.

Central processing unit

CPU capacity (Integer range) indicates the number of information that can be processed per clock (one operation). Modern CPUs can handle 32 to 64 bits. Special types of processors can be characterized by any other digit capacity (4, 8, 16, 128, etc.). Now in computer technology, 64-bit computing is increasingly being used.

Intel Pentium 4

IBM PowerPC 601

UltraSPARC III

AMD Athlon 64

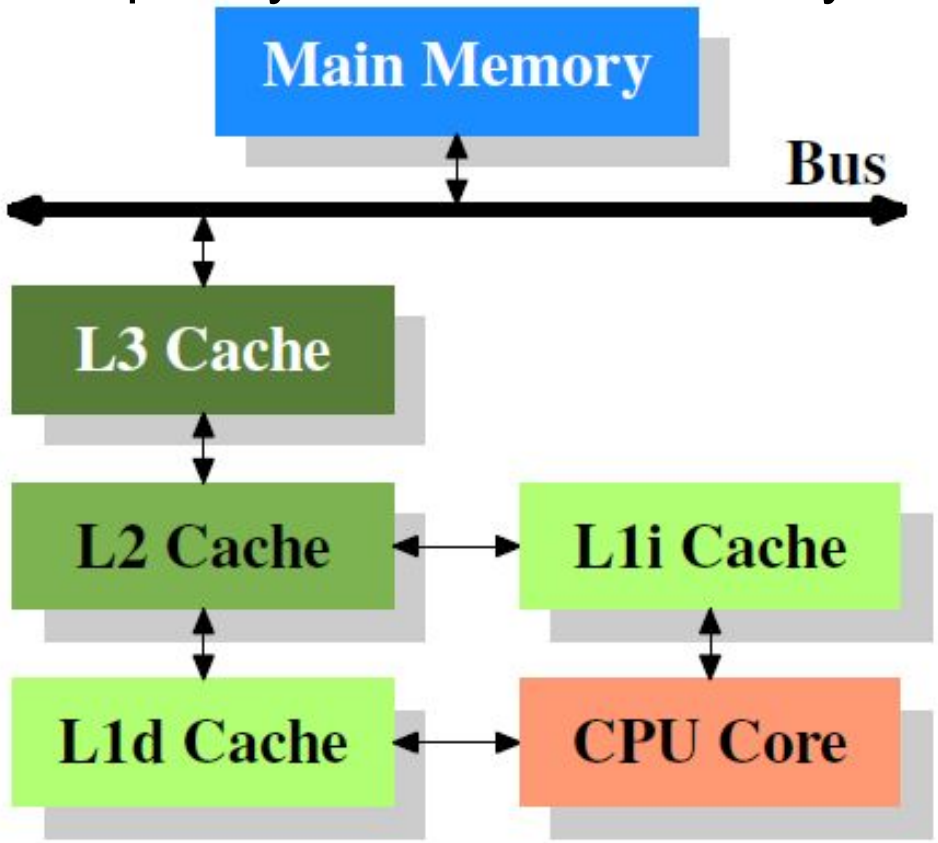
Central processing unit

CPU cache is fast memory which is needed to reduce the average cost (time or energy) to access data from the main memory. A cache is a smaller, faster memory, closer to a processor core, which stores copies of the data from frequently used main memory locations.

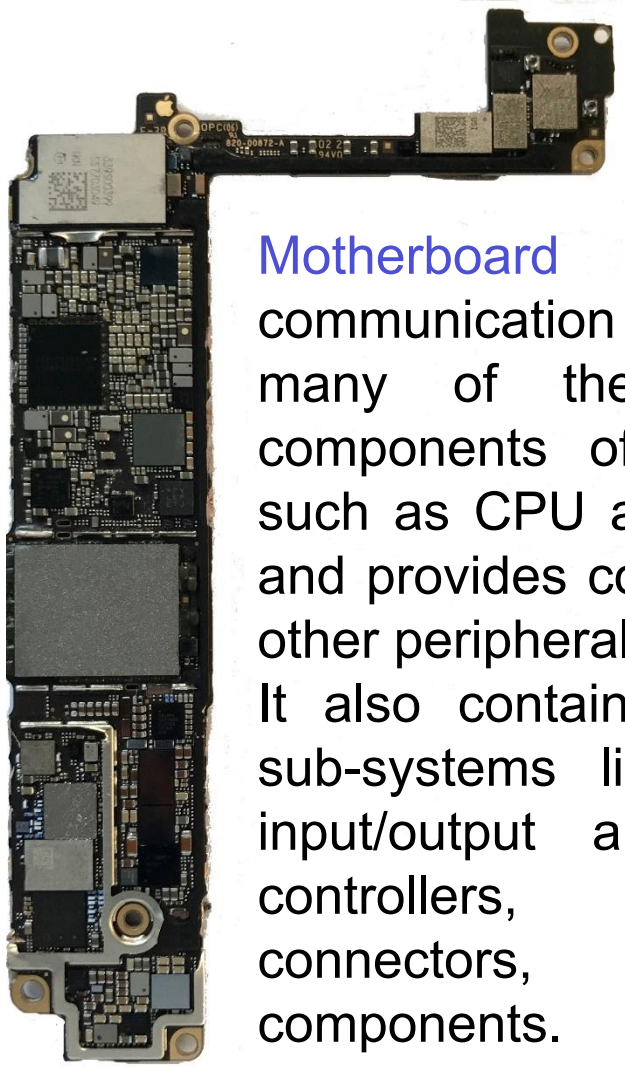
<u>There are different types of cache:</u>

- **Instruction cache** for speeding up the loading machine code
- **Data cache** helps to speed up reading and writing data
- **Translation lookaside buffer (TLB)** is a memory cache that is used to reduce the time taken to access a user memory location (address translation)

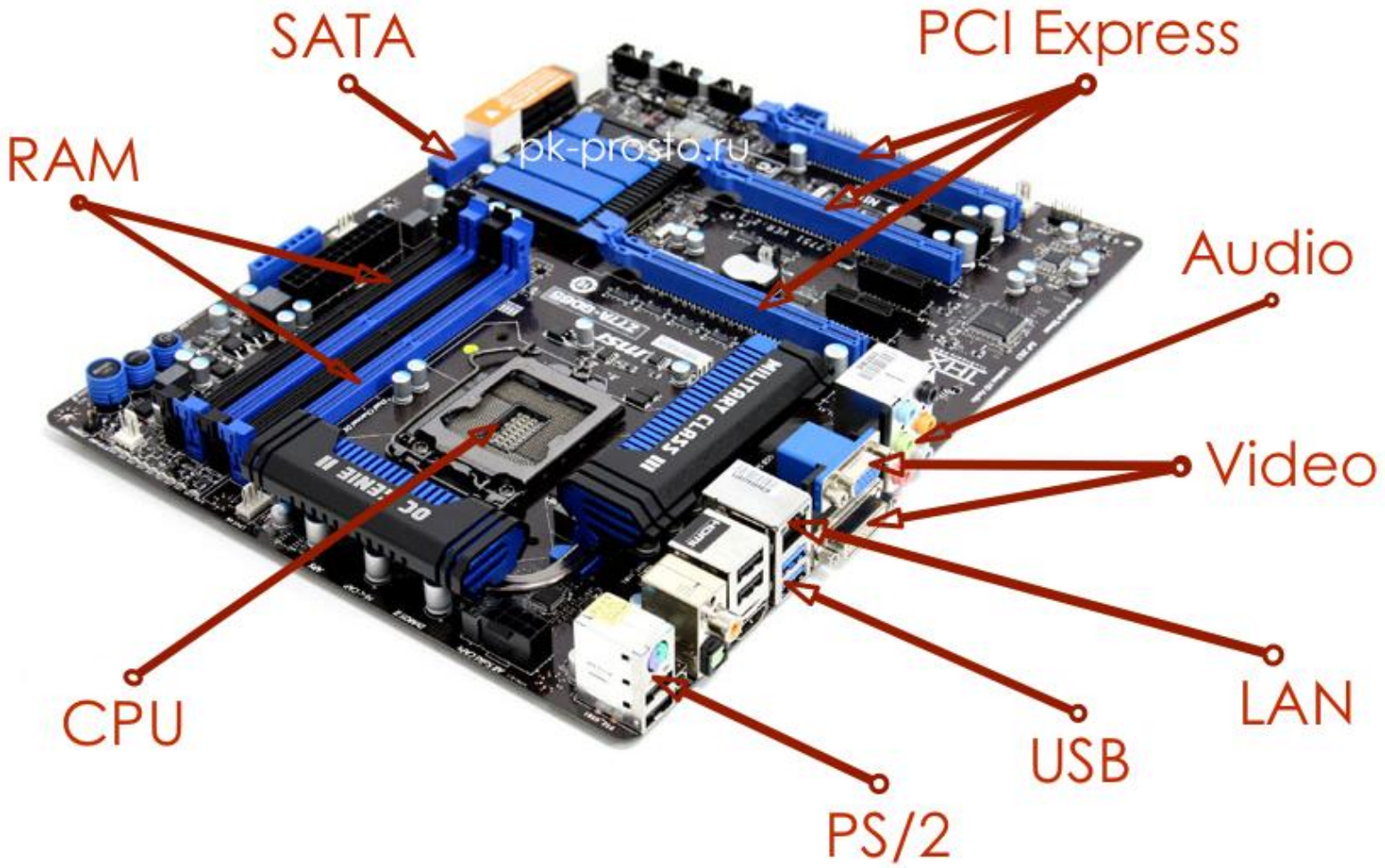
The data cache is usually organized as a hierarchy of more cache levels (L1, L2, L3, L4, etc.)



Motherboard and System interface



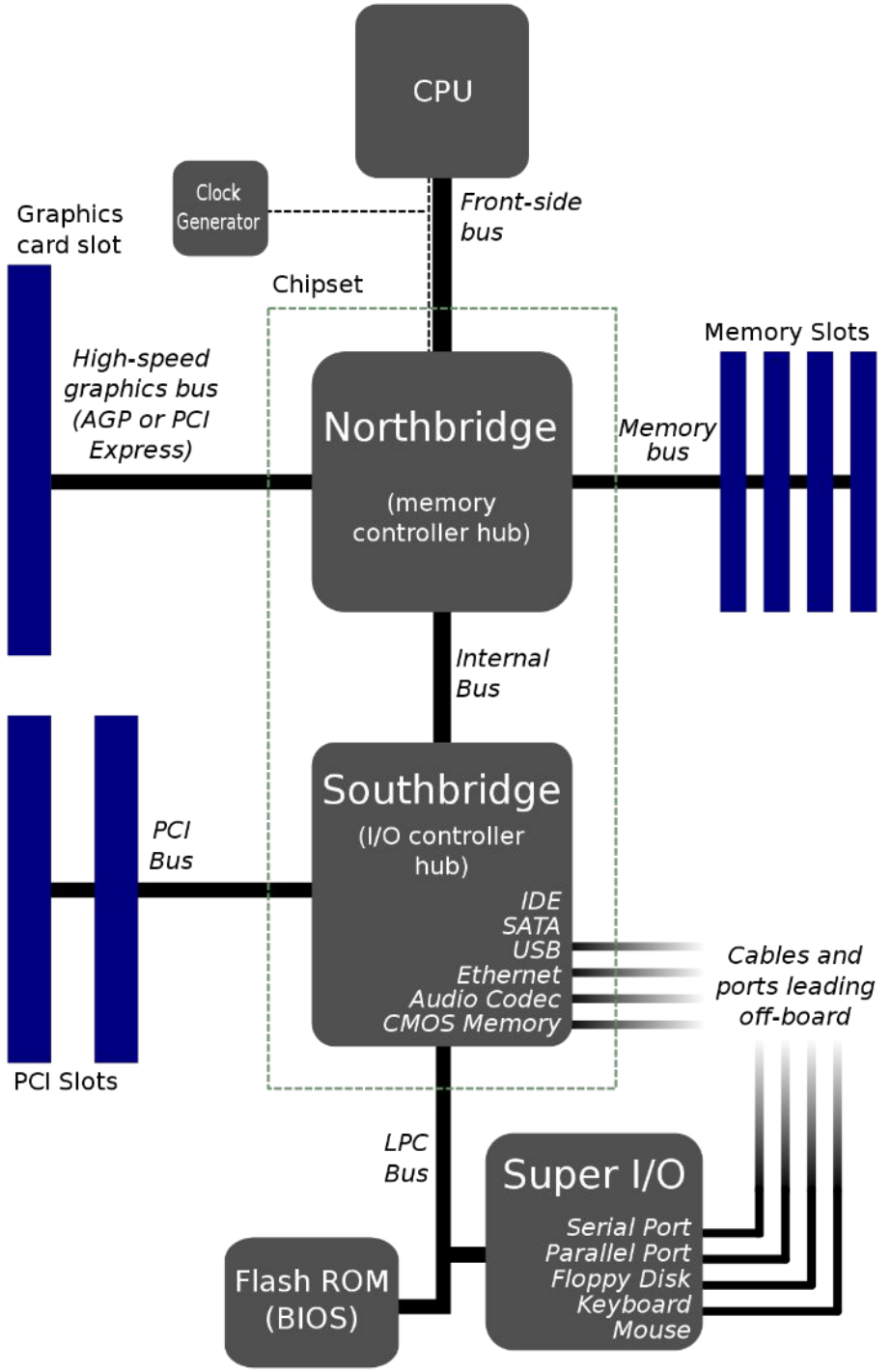
Motherboard allows communication between many of the electronic components of a system, such as CPU and memory, and provides connectors for other peripherals.
It also contains significant sub-systems like chipset's input/output and memory controllers, interface connectors, and other components.



Motherboard controllers

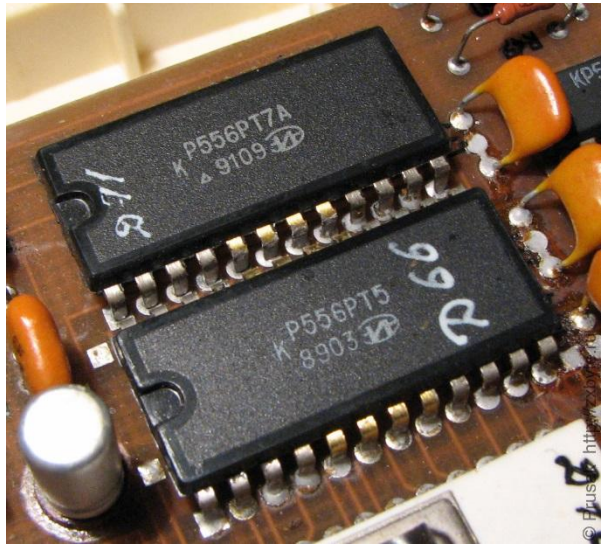
The **northbridge** (memory controller hub) typically handles communications among the CPU, RAM, and PCI Express (or AGP) video cards, and the southbridge. Some northbridge chipsets also contain integrated video controllers, also known as a Graphics and Memory Controller Hub (GMCH) in Intel systems.

The **southbridge** (I/O controller hub) handles all of a computer's I/O interfaces, such as USB, Ethernet, audio, serial, the system BIOS, SATA, IDE and some old interfaces via LPC bus.



Memory

In computing, **memory** refers to the physical devices used to store programs (sequences of instructions) or data on a temporary or permanent basis for use in a computer or other digital electronic device. Memory can be Internal (located on the system board) and External (different removable and usually portable devices like magnetic tapes hard disks, magnetic disks, optical compact disks etc.)



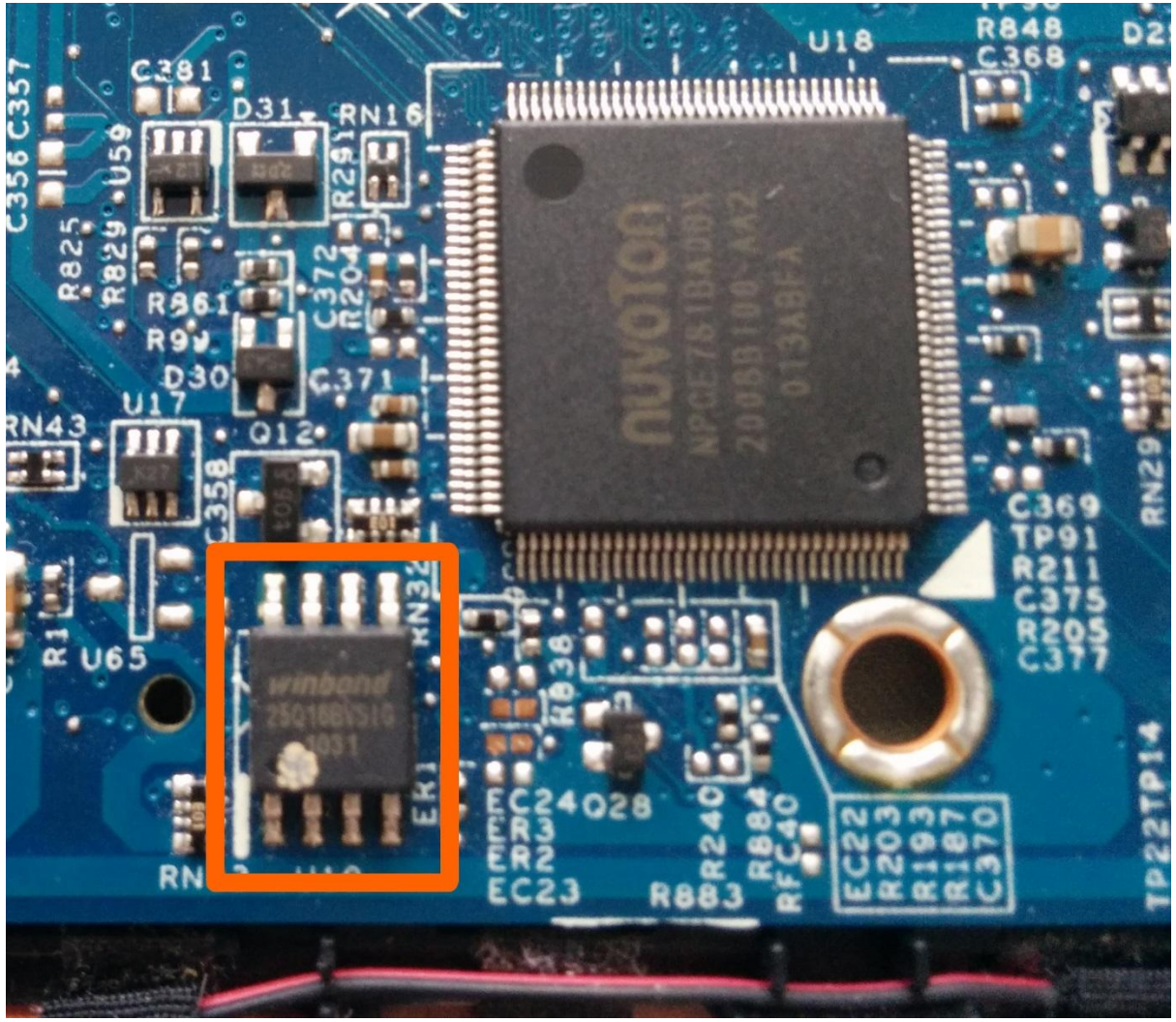
Types of Internal Memory:

- **Non-volatile memory** is computer memory that can retain the stored information even when not powered. Examples of non-volatile memory include read-only memory (ROM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM).
- **Random-access memory (RAM)** serves for the temporal storage of programs data while computer is switched on. It is volatile memory type, when the power is turned off information is lost. There are also dynamic RAM (DRAM), synchronous dynamic random-access memory (SDRAM), Double Data Rate SDRAM (DDR SDRAM), etc.
- **Cache memory** is high-speed static random access memory (SRAM) that a computer microprocessor can access more quickly than it can access regular random access memory.

BIOS

Basic Input/Output System (BIOS) is used to perform hardware initialization during the booting process (power-on startup), and to provide runtime services for operating systems and programs.

The BIOS chip comes pre-installed on a personal computer's system board, and it is the first software to run when powered on. The BIOS in modern PCs initializes and tests the system hardware components, and loads a boot loader from a mass memory device which then initializes an operating system.

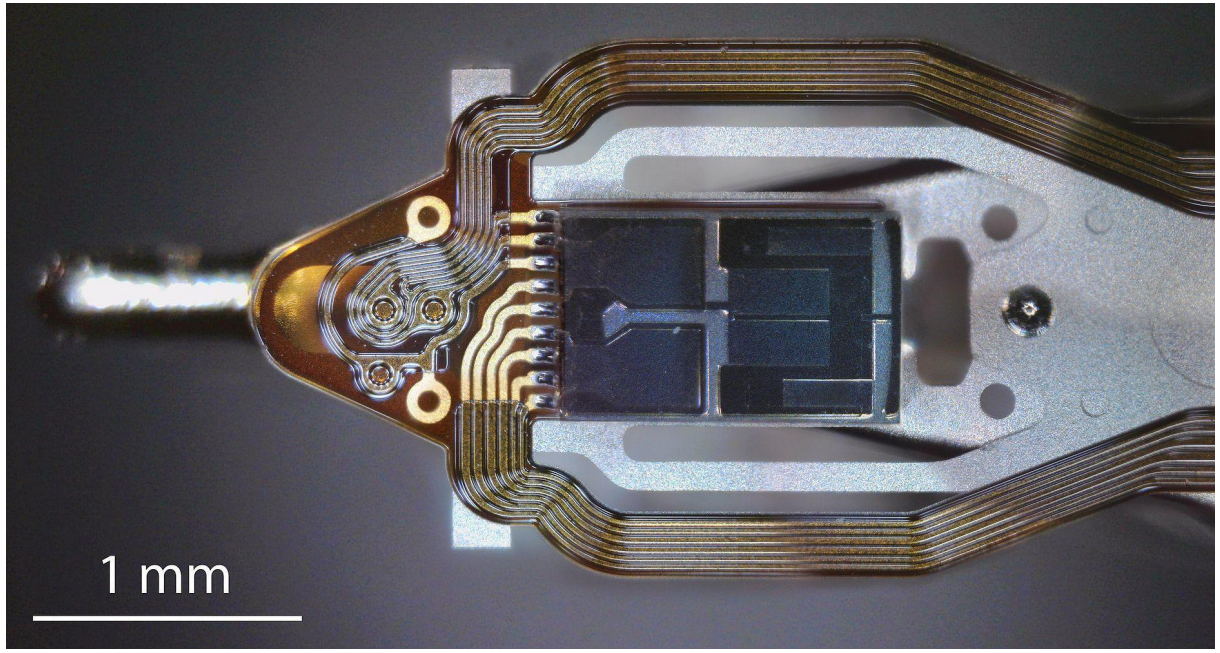


External memory

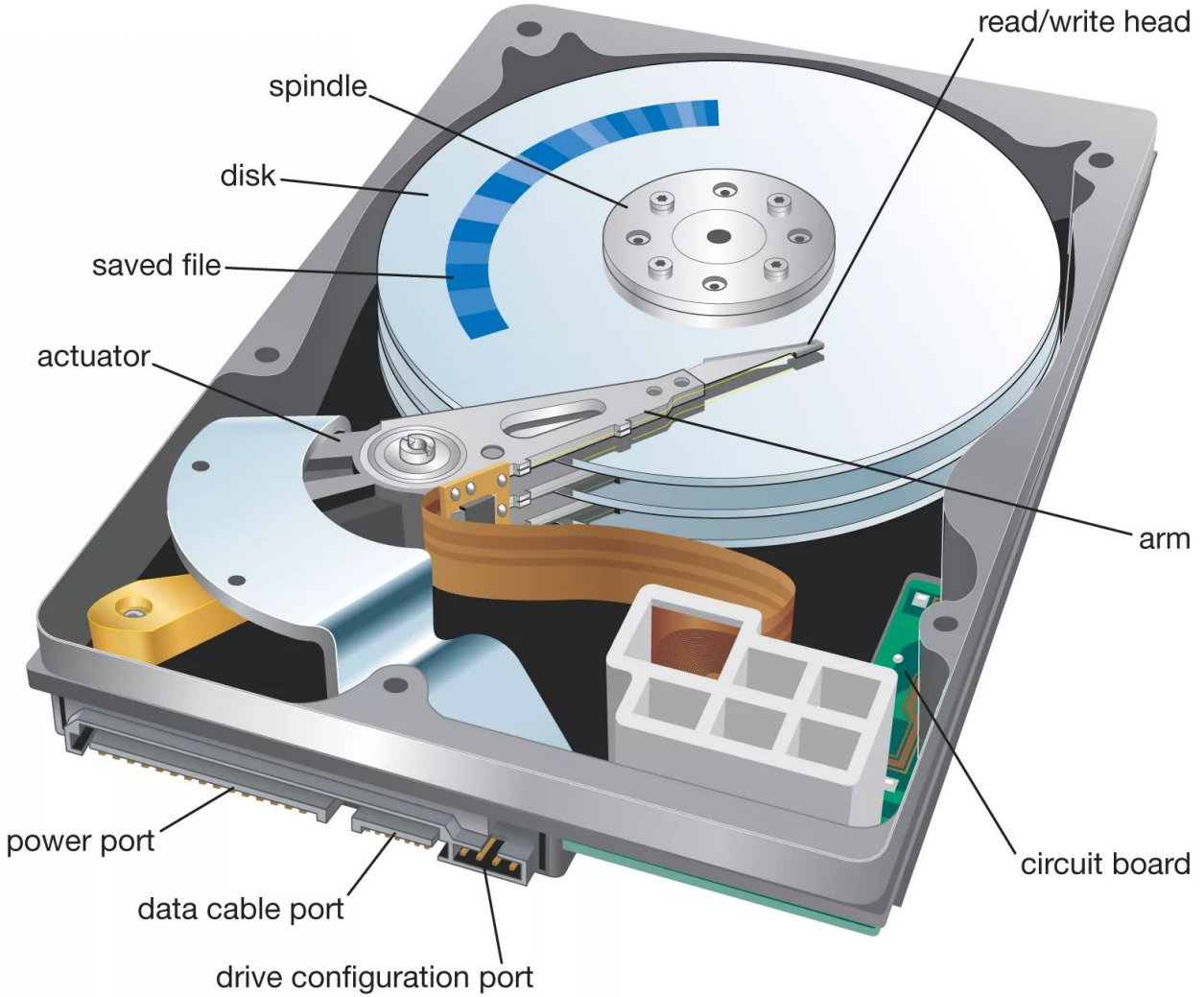
- **Magnetic tape** is a medium for magnetic recording, made of a thin, magnetizable coating on a long, narrow strip of plastic film.
- **Flexible magnetic storage (floppy disk drive, FDD)** is a type of disk storage composed of a disk of thin and flexible magnetic storage medium, sealed in a rectangular plastic enclosure lined with fabric that removes dust particles.

External memory

- **Hard disk drive (HDD)** is an electro-mechanical data storage device that uses magnetic storage to store and retrieve digital information using one or more rigid rapidly rotating disks (platters) coated with magnetic material. The platters are paired with magnetic heads which read and write data to the platter surfaces.

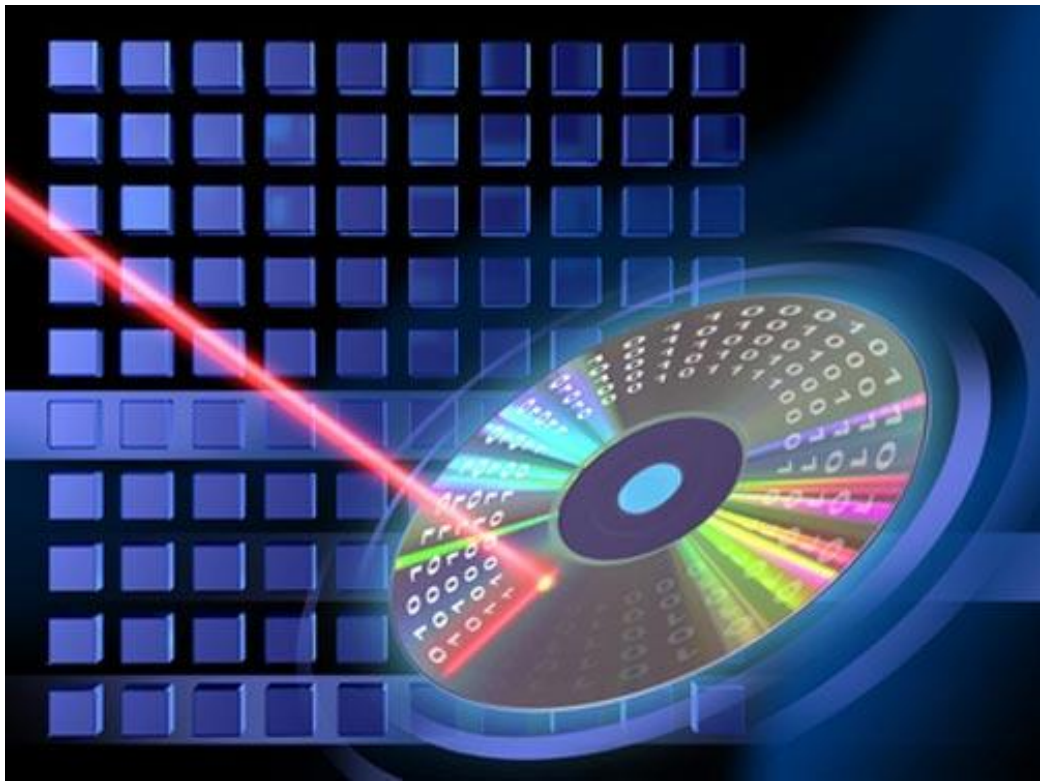


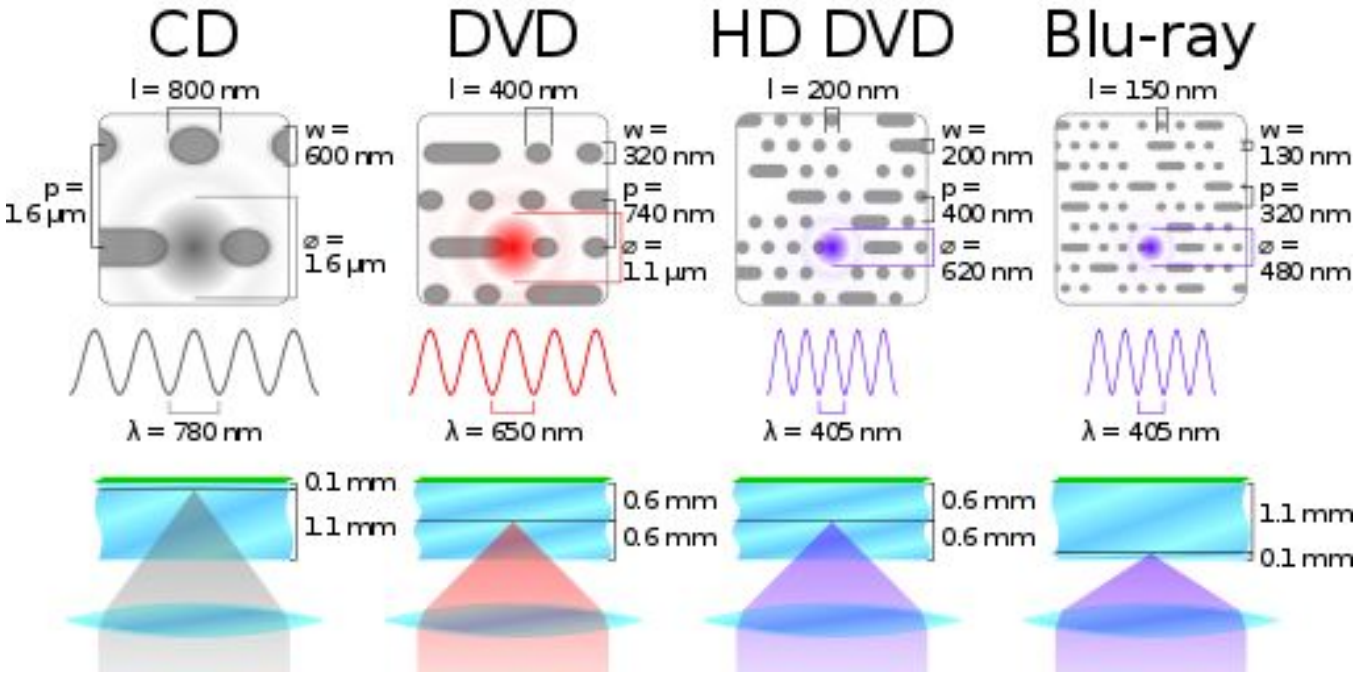
Magnetic head sensor



External memory

- An **optical disc** is an electronic data storage medium that can be written to and read from using a low-powered laser. The most common types of optical media are Blu-ray, CDs, DVDs.

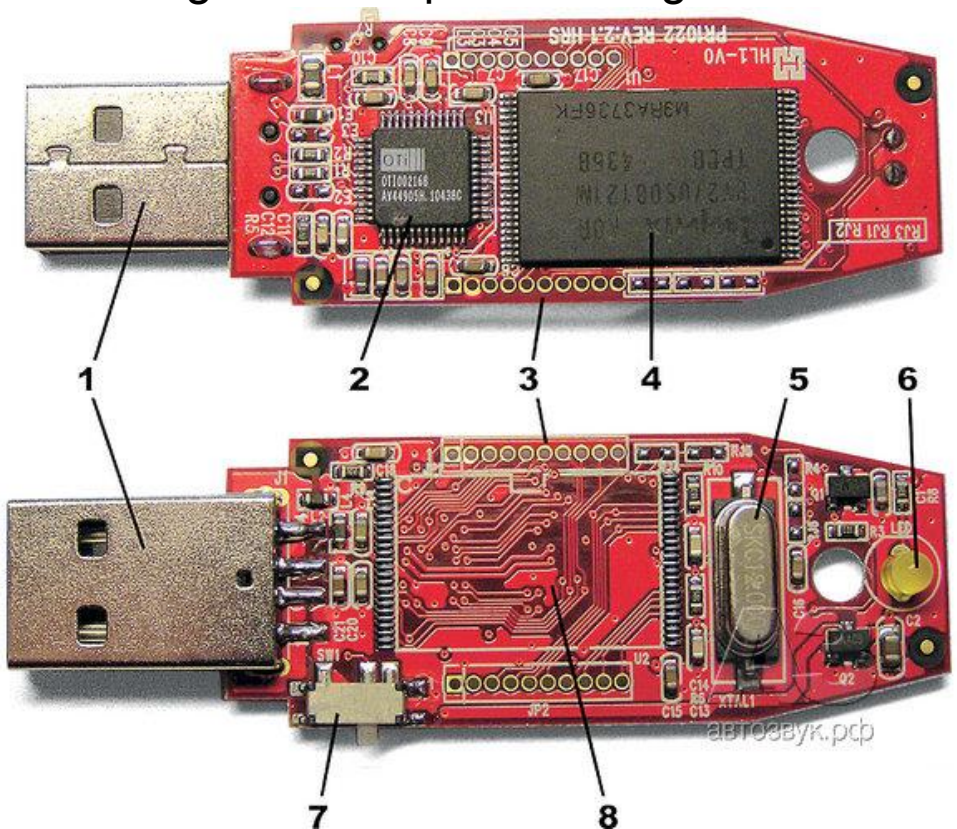




Laser encodes binary data (bits) in the form of pits (binary value of 0 or off, due to lack of reflection when read) and lands (binary value of 1 or on, due to a reflection when read)

External memory

- **Flash memory drive** and **solid-state drive (SSD)** are non-volatile computer memory storage medium that can be electrically erased and reprogrammed. A flash memory device typically consists of one or more flash memory chips (each holding many flash memory cells) along with a separate flash memory controller chip. Most SSD manufacturers use non-volatile NAND flash memory in the construction of their SSDs because of the lower cost compared with DRAM and the ability to retain the data without a constant power supply, ensuring data persistence through sudden power outages



1 - USB connector
2 - USB controller
3 - Control points
4 - Flash memory chip
5 - Quartz-crystal resonator
6 - LED indicator
7 - Write-stop switch
8 - The place for additional memory chip